Fuel Economy Policies Implementation Tool (FEPIT)

Methodology report

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Acknowledgements

The International Energy Agency (the IEA) would like to thank Davide Fiorello and Francesca Fermi, from TRT Trasporti e Territorio who, on behalf of the IEA, carried out the development of FEPIT and drafted this methodology report and the related user guide.

The IEA's Pierpaolo Cazzola and Alexander Körner elaborated the methodological framework used for the further development of FEPIT. Together with the IEA's Jacob Teter, they also provided oversight and feedback during such development of FEPIT and drafting of the related materials.

Bert Fabian (UNEP), John German (ICCT) and Lew Fulton (University of California Davis) also provided valuable inputs and comments at different stages of FEPIT's development.

Introduction

This report is made of two main parts. In the first part, the approach used to develop the upgraded version of FEPIT is introduced, the structure of the tool is presented and its functionalities described. This part mentions all methodological assumptions used to develop the tool.

The second part outlines the methodology used to quantify the elasticities of the tool. The elasticities are the parametric values that translate a policy input (e.g. a CO_2 based vehicle registration tax) into various effects leading to a reduction in the average fuel consumption. The elasticities are quantified building on the draft elasticities estimated on literature as reported in the deliverable D1. The draft elasticities have been used to simulate policies for which other literature provides impacts (or data from which the impacts can be estimated). The comparison between the literature data and the results of the simulation worked as validation of the draft elasticities and provided indications to revise the draft values.

This report is organised as follows.

Section 2 contains an overview of the structure of FEPIT.

Section 3 covers the modelling of CO_2 based vehicle registration tax/feebate scheme, as well as the methodology used to define draft elasticities.

Sections 4, 5 and 6 address CO_2 based vehicle circulation tax/feebate scheme, fuel taxation and average fuel economy target, respectively.

Section 7 documents the validation process of the draft elasticities and results in the update of the draft elasticities estimated on literature as reported in the deliverable D1. Section 7 builds on the information collected from several studies to derive impacts of vehicle taxation policies and to estimate inputs for simulating these policies in FEPIT. The assumptions used to estimate the reference elasticity values and to implement the policy in FEPIT are evaluated against each of these studies comparing the results of the application of FEPIT against their assessments. The conclusion of section 7 is the final set of the elasticities.

Overview

General structure

FEPIT estimates the effect of the application of one or more fuel economy policies, taking into account of their selection and characterization made by users, as well as information regarding the current policy and market environments (such as the level of vehicle registration tax or the level of fuel duties). The estimations of the expected impacts are based on a set of elasticities linking the policy characteristics (content and the strength) with changes in the output variable (typically the share of a given segment in the total amount of newly registered vehicles).

For comparison purposes, the tool also computes baseline fuel consumption over time, targeting a specific year, indicated by the user. This includes the evolution of the new registrations of vehicles in various segments based on technology (in case of electric / hybrid vehicles) and fuel consumption (lge/100km) classes/bins. It also includes assumptions on the evolution of the fuel consumption in each segment. In addition to fuel consumption, FEPIT evaluates also an estimate of the average tank-to-wheel CO_2 emissions per km of newly registered vehicles.

User inputs and policy simulation

FEPIT allows the introduction of assumptions defining the base year and an earlier one, the evolution of the composition of new registrations (relative importance of segments) and the average fuel consumption of each segment.

The user also defines the target year for the analysis. He/she needs to provide information on the average fuel price at the pump, the share of fuel taxes, the level of vehicle registration and circulation taxes/feebates.

The base year composition of new car registrations and the characterization of the fuel economy of each market segment are the main attributes needed for the estimation of the baseline. Newly registered vehicles are classified in five segments, defined by the user on the basis of fuel consumption thresholds (lge/100km). Hybrids, plug-in hybrid electric and battery electric cars are treated in separate segments because they have been and may well continue to be the target of specific technology policies. In total, the tool considers eight possible segments (three related to alternative technologies and five classified according to fuel consumption thresholds).

Baseline trends can be calculated assuming that the composition (and/or the average fuel consumption by segment) is the same as in the base year. Alternatively, baseline trends can result from the historical trend estimated with the base year data, combined with the same type of inputs (registration composition and average fuel consumption per segment) in an earlier year.

Two other options, based on alternative predefined trends (fast and slow development), allow the determination of other baseline trends. The fast option is partially based on observed trends estimated on EEA data by segment (although the penetration of electric cars and the improvement of their fuel consumption are fully arbitrary). Parameters under the slow development option are obtained halving the first ones.

The tool simulates the following policy measures:

- Regulatory measure on average fuel economy target
- CO_2-based vehicle registration tax/feebate scheme
- CO_2-based vehicle circulation tax/feebate scheme
- Fuel taxation

When a measure is activated, the effect of the measure in terms of changes both of the shares of new registrations by segment and the average fuel consumption by segment is determined by a set of elasticities. More measures can be activated simultaneously. When other measures are active, the elasticities measuring the impact of one measure can change. This allows accounting for interactions between measures (e.g. non-perfectly additive or more than additive effects) in the simulation.

The section below gives a brief illustration of the modelling of each measure and the type of background information it requires. All measures are then analysed in the following sections, giving details on the estimation of the elasticities used in FEPIT.

Regulatory measure on average fuel consumption target

This measure allows setting a mandatory regulatory value for the average fuel consumption (l/100 km) in the target year.

The user can define the target selecting amongst four available options: the GFEI global target on average fuel economy, the GFEI average global improvement rate, the average between the GFEI global target on average fuel economy and the GFEI average global improvement rate, and a user defined value between 0 and 7%.

- GFEI global target on average fuel economy. If this alternative is chosen, FEPIT uses as a reference the GFEI target on average fuel consumption of 4.2 lge/100 km in the year 2030. The target on average fuel economy is translated in an average improvement rate per year depending on the baseline conditions at the base year.
- GFEI average global improvement rate. If this alternative is chosen, FEPIT uses as a reference the GFEI target in terms of required annual improvement rate by -3.1%, estimated given the average global fuel economy at 2014.
- Average between GFEI global target on average fuel economy and global improvement rate. If this alternative is chosen, FEPIT uses as a reference the average value between the GFEI target as annual improvement rate by -3.1% and the average improvement rate per year corresponding to the GFEI target on average fuel consumption of 4.2 lge/100 km in the year 2030 (depending on the baseline conditions at the base year). For countries with lower specific fuel consumption than the global average of 2013 (7.1 lge/100 km) in the base year, the target specific fuel consumption will be lower than the GFEI target. In the opposite case, the calculated target will be higher than the GFEI target.
- User defined target. If this alternative is chosen, FEPIT uses as a reference an annual improvement rate defined by the user with the slider below the drop-down menu. The range of the improvement rate is between 0% and -7%. The value set using the slider is considered in the calculations only when the option “user defined target” is selected in the target option drop-down menu (when this option is not selected the check message shown bottom right the slider will display the message “Value not in use”).

FEPIT computes the reduction rate corresponding to the policy target and calculates the average fuel consumption target in the projection year using the input selected. The tool assumes that the mandatory regulatory value is met.

If other policy measures influencing fleet composition and fuel consumption are activated, the tool will compute the effect of these policies on the top of the average improvement rate needed to reach the regulatory target.

CO2-based vehicle registration taxes/feebates

It is assumed that vehicle registration taxes/feebates are differentiated depending on the CO_2 emission intensity [g CO_2/km] of the vehicle. This assumption is implemented in FEPIT differentiating vehicle registration taxes according to a segmentation (by average fuel consumption) defined by the users.

In order to estimate the impact of this measure, the tool uses a set of elasticities (see section 3 for details). The latter are defined in terms of % change of registration of a segment *s* cars when the driving cost per km changes by 1%. The actual calculation takes place in two steps:

1. elasticities are applied to each segment to compute direct impact (registration share of segment s change by x%);
2. the direct impact is compensated by changes in the other segments (for instance, if the most energy intensive class loses 2% of share, this 2% is gained by less energy intensive segments, proportionally to the relative shares they had in the base year).

For each segment, the total impact is the sum of the direct impact and the compensation. For instance, one segment can be reduced as direct impact but can gain some registrations from reductions taking place in more energy intensive classes. The balance depends on the distribution of the compensation effects. In general, gains are concentrated on more efficient segments if the cost of driving increases.

Technology policies specifically targeting HEV, PHEV and EVs are available for simulation within the registration tax policy. Namely, incentives for purchasing alternative vehicles could be implemented as rebates, producing impacts on new vehicle registration on the basis of a specific elasticity value. Nevertheless, it should be taken into account that estimates of the share electric cars in new registrations are comparatively less founded on literature than other calculations made in FEPIT.

The policy can be simulated in combination with the regulatory measure discussed earlier and/or other measures outlined below.

CO2-based vehicle circulation taxes/feebates

It is assumed that vehicle circulation taxes are differentiated depending on the CO_2 emission intensity [g CO_2/km] of the vehicle. This assumption is implemented in FEPIT differentiating vehicle registration taxes according to a segmentation (by average fuel consumption) defined by the users.

The same considerations made for CO_2-based vehicle registration taxes/feebates apply here. The simulation approach is also based on a set of elasticities (as further explained in section 0).

Circulation taxes are considered on a lifetime basis, assuming an annual discount rate of 10% applied to a vehicle mileage of 15000 km/year and 12 years of vehicle life.

The policy can be simulated in combination with the regulatory measure and/or other measures.

Fuel taxation

It is assumed that fuel taxes are modified (increased or slightly lowered) with respect to the current level (whatever the current level is: the measure can be applied also in countries where taxation is already high or when subsides are in place, initially).

The impact of the measure is estimated on both the composition of new registrations and the average fuel consumption of each segment, on the basis of elasticities (as explained in detail in section 0).

Higher fuel taxes tend to raise the importance of fuel economy for consumers, providing incentives for manufacturers to make cars more fuel efficient (eventually reducing performances), independently of the vehicle's market segment. FEPIT takes into account of two effects on new registrations by segment:

- First, the registration share of vehicles in the segment with low fuel consumption is increased and the shares of vehicles in segments with higher fuel consumption are reduced;
- Second, some registrations are shifted towards hybrid and battery electric cars.

Elasticities are defined in terms of % change of registration of segment s vehicles when the average driving cost per km (calculated over the vehicle lifetime) changes by 1%. The lifetime cost due to fuel taxes is computed assuming an annual discount rate of 10% applied to a vehicle mileage of 15000 km/year and 12 years of vehicle life.

The calculation takes place in two steps:

- elasticities are applied to each segment to compute a direct impact (registration share of segment s change by x%);
- the direct impact is compensated by changes in other segments (for instance, if the most energy intensive class loses 2% of share, this 2% is gained by less energy intensive segments proportionally to the relative shares they had in the base year).

For each segment the total impact is the sum of the direct impact and the compensation. For instance, one segment can be reduced as direct impact but can gain some registrations from reductions taking place in more energy intensive classes. The balance depends on the distribution of the compensation effects. In general, gains are concentrated on more efficient segments if the cost of driving increases.

The policy can be simulated in combination with the regulatory measure and/or other measures.

Modelling a CO2 based vehicle registration tax/feebate scheme

When a CO_2 based vehicle registration tax/feebate scheme is applied, the amount of the registration tax (or "fee") depends on the CO_2 emission intensity [g CO_2/km] of the vehicle. For cars with emissions below a certain threshold, the tax can be negative (i.e. a rebate). Assuming that new vehicles registrations are segmented into fuel consumption classes, this scheme is assumed to generate two major impacts within FEPIT:

- a shift of registrations towards lower emissions segments;
- a reduction in the average fuel consumption of cars within a specific segment.

The size of these effects depends primarily on the tax/rebate levels. In principle, context elements assumed to play a role in defining the value of the elasticities are:

- the average income per capita;
- the initial level of fuel price.

However, as explained below, no convincing evidence has been found that income level affects the type of elasticities used in the tool.

Furthermore, it is assumed that other measures can interact with a CO_2 based vehicle circulation tax/feebate scheme, modifying its effects.

The following paragraphs describe in detail the elasticities estimated to reproduce these effects in FEPIT and the reasons leading to their identification.

Base elasticity values

Impact on the new registrations by segment

A useful source to estimate the impact of a CO_2 based vehicle registration tax/feebate scheme on registration by segment is the study of D'Haultfœuille et al. (2012). The authors of this paper estimate the impact of the French feebate system and provide parametric estimates of the resultant response in registrations by segment. These parameters measure the same effect that FEPIT aims to reproduce. They are therefore a very useful starting point.

It is important to note that the impact of the French feebate system on market shares evaluated in this paper[1] relate to a specific segmentation of vehicles. For segments with no registrations or for which the registration tax was zero under the French scheme, parameters are not estimated. In the case of the FEPIT tool, more general elasticities are required.

Another study by Klier and Linn (2012) is also based on the French feebate scheme, estimating the effect of tax changes on vehicle registrations; nevertheless, only a single value is provided[2], rather than segment-specific values. The magnitude of this parameter is consistent with the values estimated in D'Haultfœuille et al.

Similar values on the impact of a vehicle registration tax/feebate on car market shares by segment are reported in Rivers et al. (2014)[3] related to the new vehicle feebate in Canada. Other literature

[1] We refer to values in Table 5, page 27 of paper.
[2] We refer to values in Table 2, page 49 of paper.
[3] In the Canadian market, imposing a fee of $1,000 reduces the market share of a vehicle by approximately 30% relative to a counterfactual where no fee is applied.

with similar results related to vehicle taxes and subsidies includes Chandra et al. (2010)[4], who analyse hybrid vehicle rebate programs in Canada; Diamond (2009),[5] who examines hybrid vehicle rebates in the US; and Adamou et al. (2014),[6] who consider a prospective German feebate program. Most of these analyses are applied in North American countries where a consistent difference in fuel prices is observed with respect to Europe: the values should therefore be evaluated taking into account this aspect (see paragraph 0).

The value of elasticity estimated in Klier and Linn in terms of impact of a CO_2 based vehicle registration tax/feebate scheme on the share of registrations by segment is chosen as a reference here. This is complemented by a significant result reported by D'Haultfœuille et al.: the elasticity of registrations with respect to feebates is quite low for cars in the upper segments (i.e. larger cars with high fuel consumption). The authors explain this by arguing that those purchasing very large cars are probably already aware of their environmental impact but are not very concerned about it. This complementing element is useful to reflect the fact that vehicle purchases in the upper segments are probably less sensitive to a CO_2 based vehicle registration tax in the elasticities taken into account for FEPIT. The value estimated by Klier and Linn has therefore been used for all segments except for the one associated with the highest fuel consumption.[7] For this segment, the elasticity value is halved (in D'Haultfœuille et al. the elasticity of larger cars is roughly one half of the elasticity for other segments).[8]

The parameters estimated in the papers mentioned above are given in terms of change of the natural logarithm in car registrations in a given segment in response to a 1000 Euro tax/rebate. The tax (measured in 2005 Euro in the Klier and Linn paper) is the one applied to that segment.

Taking into account that FEPIT works in US dollars and updating currency values from 2005[9], the base values for the elasticity of the share of vehicle registrations by segment to a CO_2 based vehicle registration tax/feebate scheme are those reported in Table 1.

Table 1: CO_2 based vehicle registration tax/feebate elasticities of registrations by segment

Segment	Elasticity[(a)]
All	-0.70
Higher fuel consumption segment	-0.35

(a) intended as the change of the natural logarithm of the registrations of cars in a given segment when a 1000 $ tax/rebate

Using this type of elasticity the size of the impact depends on the initial registration share. For instance, assuming that the base registration share for a segment of cars is 15.9% and a 750$ tax is applied to this segment, the elasticity works as follows:

Initial share: 15.9%

[4] A $1,000 hybrid vehicle rebate in Canada has the effect of increasing market share by around 35%.
[5] An $830 hybrid vehicle rebate in the US results in an increase in hybrid market share of about 18% (for the Ford Escape model).
[6] A €1,000 reduction in vehicle price is associated with a 20% increase in vehicle market share in the German context.
[7] The segments in FEPIT are not based on fixed thresholds so the level of fuel consumption corresponding to the upper segments is not always the same.
[8] The parameters for the two segments corresponding to larger cars are of the size of 0.15 whereas for other segments the absolute value is in the range 0.25 – 0.70 (for one segment, the elasticity is 0.01, but the parameter is not significant).
[9] The GDP deflator of the Euro area between 2005 and 2014 is around 1.15 Euro according to the World Bank database. The PPP conversion factor between US dollars and Euro (from the same source) has been quite stable, around 1.1, since 2005 (1 $ = 1.1 €). Klier and Linn's estimate of -0.56 is based on 1000 Euro in 2005 currency corresponds to -0.56 * 1.15 * 1.1 = - 0.7 in current 1000 US dollars.

Log of initial share: -1.839

Change in Log induced by the tax: -0.70 * 750 /1000 = -0.525

New log share: -2.364

New share: 9.4%

These elasticities apply to the impact of feebates targeting a specific segment. When they are applied to all segments, the new shares do not generally sum to 1 (e.g. if the scheme consists only of taxes without any rebate, all shares will be reduced and so the sum will necessarily be lower than 1). In FEPIT, the volume of registrations lost or gained by each segment is redistributed across other segments in order to guarantee that the sum of shares equals 1. This means that the final new shares will not match those initially estimated using the elasticities. The implications of adding this aspect to the calculation is addressed in the validation exercise (see section 7).

Impact on the average fuel consumption by segment

The shift of registrations between different segments is an effect of CO_2 based vehicle registration tax/feebate schemes. The same effect can also lead to change the distribution of the registrations within the segments (it depends on the definition of the segments whether a switch to another segment is observed or not) and the deployment of technical improvements.

Estimating the effect of CO_2 based vehicle registration tax/feebate schemes within segments can be achieved by comparing segment-specific average fuel consumption of newly registered vehicles before and after the application of the scheme.

A study conducted by COWI (2002) estimates the effects of various taxation strategies using a vehicle choice model[10]. The model estimates the impact on the average CO_2 emissions of a CO_2-based vehicle registration tax under the assumption that the registration shares are not changed. This assumption provides the framework needed here for estimating the improvement of fuel consumption within segments. Results are provided for various countries[11] under the assumption of different tax levels.

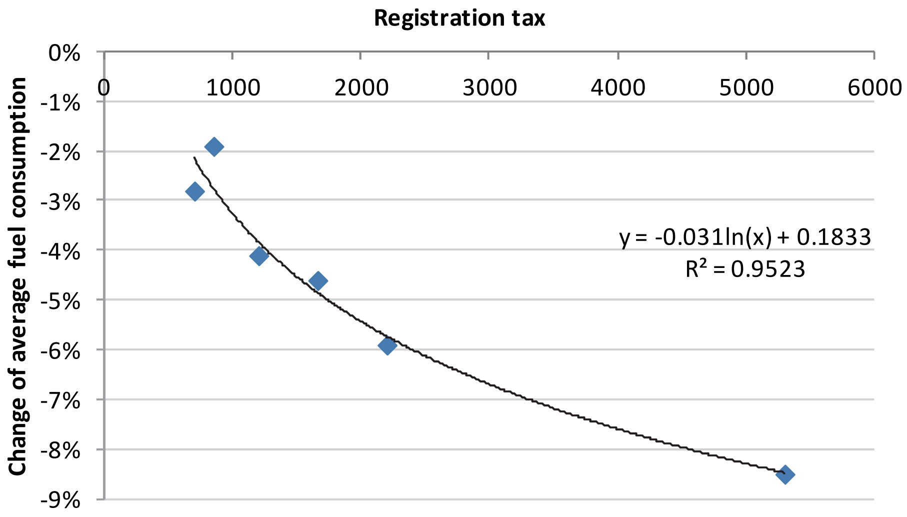
As shown in Figure 1, estimates for gasoline cars fit nicely a logistic decay curve. The curve shows the estimated effect of the tax scheme based on the average value of the tax, weighted by the initial registration shares. The magnitude of the impact is generally quite small – when the average value of the tax is 500 $, the effect is about a 1% reduction in fuel consumption. This is consistent with the finding reported by Bunch, Greene et al. (2011) who, making reference to the experience in the US, say that feebate systems reduce average emissions primarily by inducing shifts in sales across segments, whereas redesign (within segments) plays a minor role.[12]

[10] The choice to rely on this study is primarily due to the lack of studies estimating segment-specific average fuel consumption of newly registered vehicles in different segments, before and after the application of a CO_2 based registration tax/feebate scheme. The European Environment Agency (EEA) provides detailed data on new vehicle registrations that could have been used to develop a specific analysis, but the earliest year available is 2010 – a date when CO_2 based vehicle registration tax/feebate schemes were already in force in Europe.

[11] We refer to the data provided in tables reported in Annex E of the report.

[12] Greene, Patterson et al. (2005) argued just the opposite, i.e. that the “vast majority of fuel economy increase is due to adoption of fuel economy technologies rather than shifts in sales”. However, as Bunch, Greene et al. (2011) pointed out “that analysis did not assume base cases with continually increasing fuel economy standards. With increasingly stringent standards a greater proportion of the impact of feebates comes about through shifting the sales distribution toward lower emission vehicles.”

Figure 1: Fuel consumption reductions generated by registration tax under a fleet neutrality assumption



Source: estimation elaborated on the basis of COWI (2002) data.

The curve estimated on COWI data (Figure 1) was used as an elasticity measuring the effect of a CO_2 based vehicle registration tax/feebate scheme on average fuel consumption within each segment[13] . Using the GDP deflator to update 2002 data, the equation describing this elasticity becomes:

*%FR = -0.037 * ln(T) + 0.2238* [eq. 1]

Where T is the weighted average value of the tax.[14]

Context factors influencing the base elasticities

Base elasticities introduced above are drawn from studies that are generally based on the experience of vehicle taxation in Europe. Europe is characterised by:

- Relatively high average levels of fuel efficiency of new registrations;
- Relatively high average income per capita;
- High fuel prices.

The effect of vehicle taxation may potentially be quite different in other contexts. The initial registration mix can be considered to be influenced by two explanatory variables: income level

[13] This means using the average tax resulting from the taxes applied to each vehicle subset weighted by the number of vehicles registered in each subset as the driving parameter for computing the size of the effect within each subset.

[14] When a feebate scheme is applied the tax value for some segments is negative. The average computed considering these negative values can be quite low in cases (like e.g. the French scheme) where a large share of registrations benefits from a rebate. We argue that both negative and positive taxes work as an incentive to improve fuel economy and so the average tax should be computed using the absolute values of the fee for each segment. For instance, assume for sake of simplicity that three segments are defined. The first segment includes 5% of cars and receives a rebate of 1000 $; the second segment includes 70% of cars and pays a fee of 500 $; The third segment includes 25% of cars and pays a fee of 2000 $. In order to apply equation 1 we compute the average tax level as 1000 x 0.05 + 500 x 0.70 + 2000 x 0.25 = 900 and not as -1000 x 0.05 + 500 x 0.70 + 2000 x 0.25 = 800.

and fuel prices. Hence, these two parameters are assumed to influence the elasticities and tested on this aspect.

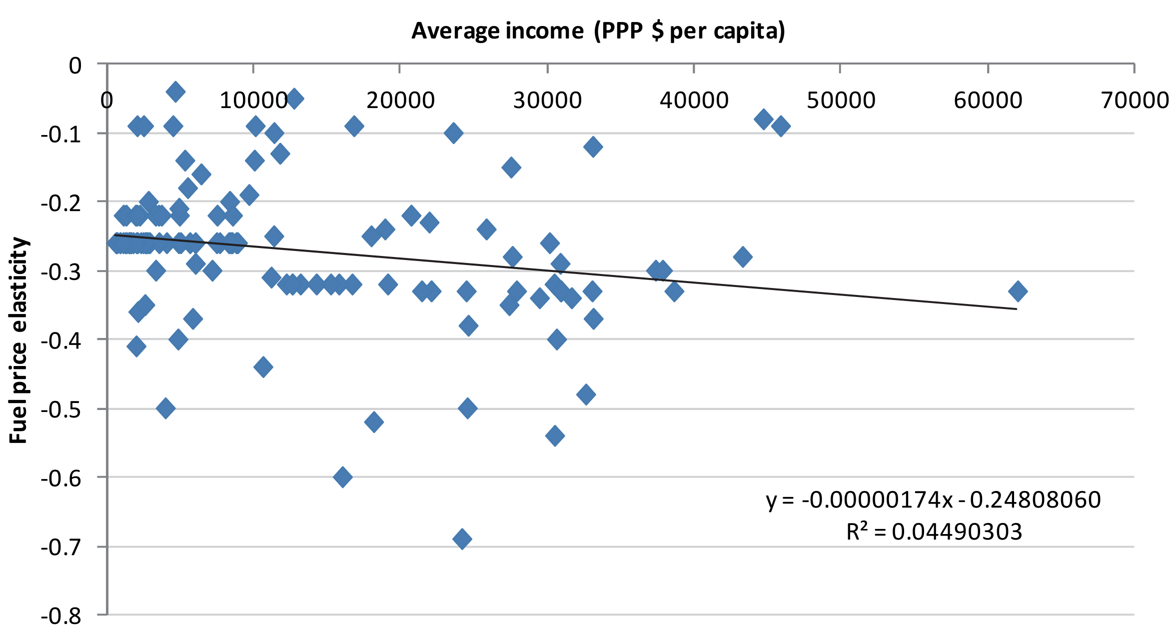
Effect of the average income per capita on the elasticities

Here we seek to estimate how the sensitivity of registrations of vehicles in a given segment with respect to some policy lever might vary under different income levels – which are proxied here by national levels of aggregate GDP per capita. The question to be answered is therefore the following one: is the value of the demand elasticity parameter in less affluent countries smaller or larger?

According to Dahl (2012), who analyses a large sample of countries, the elasticity of fuel consumption to fuel price is lower in countries with lower average income. This finding may indeed seem counterintuitive, as one would expect elasticities to be lower in richer countries. Dahl argues that this can have two explanations: "In poorer countries, only the relatively rich may have personal vehicles, and they may be less responsive to price changes. Alternatively, poorer countries tend to have higher capital costs and anecdotal evidence suggests that they keep their vehicles longer. Thus, their vehicle stock turns over more slowly to newer more fuel efficient vehicles lowering their price responsiveness". This conclusion is also supported by Fouquet (2012) and Hughes et al. (2006).

Dahl's data, however, only allow discerning a weal statistical relationship behind the positive correlation between income and elasticity (see Figure 2)

Figure 2: Relationship between fuel consumption price elasticity and average income per capita



Source: estimation elaborated on the basis of on Dahl (2012) data

Since there is not sufficient evidence to support the quantification of a parameter and theoretical considerations are also not necessarily conclusive, the choice is to not include in FEPIT any adjustment based on income.

Effect of the baseline fuel price on the elasticities

According to the results presented in Bunch, Greene et al. (2011), a feebate programme in California based on a 20 $/(g CO_2/mile), equal to 12.5 $/(g CO_2/km) registration tax would improve average CO_2 emissions of new vehicles by roughly 12 g CO_2/mile (7.5 g CO_2/km)[15]. Since the reference value is of 300 g CO_2/mile (187.5 g CO_2/km), this equates to an improvement of 4%.

This effect is smaller if compared with the estimate provided by Klier and Linn (2012) on the impact of feebates in France. In France, the estimated reduction[16] of CO_2 emissions is roughly 8 gCO_2 /km, from an initial value of about 150 gCO_2 /km, which translates to an improvement of nearly 5.5%. Furthermore, this result is obtained assuming a level of registration tax in the US test case which is higher than the registration tax presented in the France scheme (with taxes in a range between 1700$ and 3500$ in the US, while in France the range is from a rebate of about 6300 $ to a tax of about 3200$).

As the size of the taxes on vehicles (e.g. registration or circulation) is not significantly different in the US case than in the French case, it seems fair to assume that the differences in terms of registration mix and of fuel price between EU and the US explain the lower responsiveness of the latter to vehicle taxation.

Therefore, a reduction of the elasticity parameters is required to simulate the lower responsiveness related to fuel price differences with respect to the EU reference case. The estimation of the size of the reduction in the elasticity has been based on the implementation of data on new registrations in the US and simulating the feebate programme reported by Bunch, Greene et al. According to this approach, base elasticities would need to be cut by 80%, i.e. the change in the coefficient (of the natural logarithm of the registrations of cars in one segment when a 1000 $ tax/rebate is applied) would be -0.14[17] instead of the base value of -0.70 estimated above (see Table 1) .

The range of the adjustment is confirmed by the values reported in the following analyses:

- Rivers et al. (2014), who analyse the new vehicle feebate in Canada;
- Chandra et al. (2010), who analyse hybrid vehicle rebate programs in Canada; and
- Diamond's (2009) study of the hybrid vehicle rebate in the US.

The average gasoline price in the US was about 1 $/litre, roughly half of the value of Europe (2 $/litre). Assuming that the difference in elasticity estimated above is explained by this difference in fuel prices, a parameter to correct the base elasticities when the fuel price is different from the EU level can be defined as follows:

*Elast = Base Elast * [1 + 1.6 *(Fuel Price / Base Fuel price -1)]*

*Elast = 0.70 *[1+ 1.6 * (Fuel price /2 -1)]* [eq. 2]

Interaction with other measures

When multiple measures are activated simultaneously the overall impact is not necessarily the additive sum of the impacts of the single measures.

[15] We refer to results on page 166 of the report.
[16] We refer to results in Table 2 page 49 of the paper.
[17] -0.7 * (1 – 0.8) = - 0.14 in current 1000 US dollars.

Interaction with circulation taxes/feebates

The COWI study cited above (COWI, 2002) estimated the effect of a registration tax, the effect of a circulation tax, and the effect of the combination of the two. The analysis concluded that, when a certain taxation level is applied by combining the two taxes, the effect on the average fuel consumption is larger than the effect that would arise if the two measures were applied separately. The two taxation schemes are not perfectly additive. According to the COWI study, this happens because in most of the countries one of the two taxes does not exist, is very low (and hence has virtually no effect), or is only poorly correlated with fuel consumption. This means that the combination of two CO_2 based taxes introduces a new signal, and this leads to a larger response.

Using the results provided by the study,[18] based on nine different countries, it can be computed that, on average, a certain amount of vehicle tax levied as combination between registration and circulation tax gives rise to 30% more fuel consumption savings than would be the case if the two taxes were perfectly additive.

This estimate was taken as a reference value for FEPIT: when the two vehicle taxes are applied simultaneously in FEPIT, the sum of the combined impact is multiplied by 1.3.

Interaction with fuel taxes

As mentioned above (3.2.2), the elasticities are adjusted to take into account the initial level of fuel price (Equation 2). If one assumes that a change in fuel tax brings about the same effect of a change of fuel price, the same adjustment (Equation 2) must be applied.

Interaction with a fuel consumption (emissions) target

FEPIT allows introducing a fuel consumption target (broadly corresponding to an emissions target) and assumes that this target is always met, i.e. that the fuel consumption of newly registered cars is progressively reduced, reaching the target value in the target year.

When a fuel consumption target is set, FEPIT considers that the responsiveness to a CO_2 based registration tax/feebate scheme is reduced. This is based on the consideration that, as vehicle efficiency gradually improves, the incentive to choose a more fuel efficient car also gradually declines.

In order to quantify the reduction in the responsiveness to registration tax/feebate schemes, choosing a vehicle with a given fuel consumption is assumed to correspond to the selection of a stream of fuel expenditures resulting from the fuel consumption characteristics and the vehicle mileage profile. A tax/feebate scheme is designed to induce a shift in consumption choices towards more fuel-efficient cars, i.e. to induce a reduction in fuel consumption. All else being equal (i.e. with mileage and fuel price unchanged), this reduction in specific fuel consumption would lead to a reduction of the stream of fuel expenditures mentioned earlier. This is because fuel expenditures are the product of mileage, specific fuel consumption, and fuel price. The same reduction in fuel expenditures could be driven by a reduction of the fuel price having the same proportion (all else being equal, i.e. without changes in mileage and fuel economy characteristics) of the change in the specific fuel consumption just discussed. Again, this is due to the fact that fuel expenditure is the product of fuel price, specific fuel consumption and mileage. These considerations show that a lower incentive to shift towards vehicle classes with a lower fuel consumption could be driven either by a change in the average fuel economy (towards lower

[18] We refer to the data reported in Annex E of the report.

values) or by a change of the same magnitude of fuel prices (also oriented towards lower values). Therefore, the impact on fuel consumption related to the introduction of a fuel consumption target could be estimated as an impact related to changes in fuel price (in relative terms). In order to quantify the related reduction in elasticity, equation 2 (related to different baseline fuel price conditions) can be used.

The interaction between CO_2 based registration tax/feebate scheme and fuel consumption target is therefore simulated as follows:

1. computing the reduction of the average fuel consumption induced by the target,
2. estimating the relative reduction of the average lifetime fuel expenditure,
3. interpreting this relative reduction as if it were a reduction of the fuel price,
4. estimating the corrected value of elasticity applying the resulting value of fuel price in equation [2].

Modelling a CO2 based vehicle circulation tax/feebate scheme

This policy consists of setting the level of the circulation tax according to the CO_2 emission level or the unitary fuel consumption of the vehicle. In general, the higher the emission level, the higher the tax. As in the case of registration taxes and feebates, below a certain threshold the circulation tax can be negative, i.e. car purchasers enjoy a rebate. Circulation taxes/feebates are due each year and may be conceived in an evolutionary manner, starting from a certain value and evolving in a way that is not necessarily constant over the vehicle life. Rebates, in the case of circulation taxes/feebates, are much less frequent than in the case of registration taxes/feebates, and rather unlikely when taking into account the average value of the circulation taxes/feebates over the vehicle life.

This scheme is supposed to generate the same type of impacts of a registration tax within FEPIT:

- A shift of registrations towards lower emissions segments.
- A reduction of average fuel consumption of cars within a specific segment.

Base elasticity values

Impact on the new registrations by segment

In principle, one might assume that the vehicle lifetime cost of the yearly circulation tax is equivalent to a registration tax of the same amount (e.g. a 500 $ circulation tax paid every year for 12 years is equivalent to a 6000 $ registration tax). Under this simplifying assumption, the same elasticities defined above could be used and applied to the lifetime equivalent of the circulation tax.

However, according to the results provided by Klier and Linn (2012), where the effect of the French registration feebate scheme is compared to the impact of the circulation tax in Germany and Sweden, impacts due to circulation taxes seem to lead to fewer changes in the registration mix than in France. The authors were not able to demonstrate that the lower elasticities estimated in countries where the circulation tax is used rather than the registration tax were in fact due to the different characteristics of the taxation schemes. However, since annual circulation taxes are generally larger than the ratio between the registration tax and average car lifetime, and since consumers tend to value more expenditures occurring in the near term with respect to expenditures taking place in the future (discounting), it is reasonable to expect that the elasticity applied to circulation taxes is lower than the one relevant for registration taxes. The lower elasticity characterizing responses to circulation taxes (with respect to registration taxes) is also confirmed by another literature source[19], stating that “consumers are generally more responsive to price changes when purchasing a car as compared to the annually recurring car taxes”.

Once the lifetime[20] expenditure is considered, Klier and Linn estimate that the elasticity of registrations to a circulation tax is about one third of elasticity to registration tax in Germany and

[19] This statement is made in Geilenkirchen, G.P., Geurs, K.T., van Essen, H.P., Schroten, A., Boon, B. (2009), Effecten van prijsbeleid in verkeer en vervoer, Bilthoven: Planbureau voor de Leefomgeving, CE Delft and reported (translated) in Kok (2011).

[20] “Lifetime” means that the yearly tax is multiplied for the assumed numbers of years of car life (12 years in Klier and Linn) and future values are discounted (with a 10% discount rate in Klier and Linn).

one eighth of the registration tax elasticity in Sweden.[21] For FEPIT, an average of one fifth is assumed. The base values for the elasticity of the share of vehicle registrations by segment to a CO_2 based vehicle circulation tax/feebate scheme are those reported in Table 2.

Table 2: CO_2 based vehicle circulation tax/feebate elasticities of registrations by segment

Segment	Elasticity[(a)]
All	-0.14
Higher fuel consumption segment	-0.07

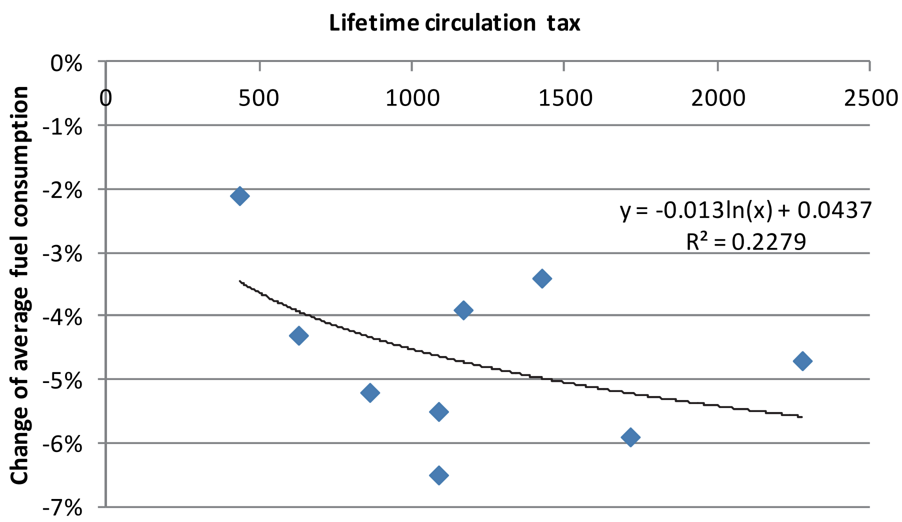
(a) change of the natural logarithm of the registrations of cars in one segment when a 1000 $ tax/rebate is applied

The same logic applied to the base elasticities to registration tax applies in the case of circulation taxes: these elasticities refer to the impact on a specific segment. In FEPIT, the shares of registrations lost or gained by each segment are redistributed across other segments in order to guarantee that the sum of shares is 1.

Impact on the average fuel consumption by segment

The second expected impact of the CO_2 based vehicle circulation tax/feebate scheme is to reduce the average fuel consumption within each segment. The COWI (2002) study used to quantify the elasticity for a registration tax reports also estimates the impact of the application of circulation tax on CO_2 emissions under the assumption that registration mix is not changed (fleet neutrality). Unfortunately, the data available in this study do not fit any clear pattern (see Figure 3). The report does not provide elements to explain why the impacts of a registration tax and a circulation tax are so different. One reason might be that in all countries considered in the study a circulation tax already existed in the base scenario and was already differentiated in some way among vehicle segments, whereas in some countries the registration tax was null or very small. Therefore, while the average value of a CO_2 registration tax is a reasonable representation of the scheme, the average value of the circulation tax is not, as one should analyse values by segment (but this detail is not available in the study).

Figure 3: Fuel consumption reductions generated by circulation tax under a fleet neutrality assumption



Source: estimation elaborated on the basis of COWI (2002) data

[21] We refer to results presented at page 19 of the paper.

Whatever the reason, it is estimated here that the equation estimated from the data reported in the COWI study is not sufficiently robust to be adopted.

The limited availability of other data on this effect led to the decision to adopt an assumption of proportionality: if the effect of a circulation tax on the registration mix is lower than the effect of a registration tax (see section 3.1.1), it seems reasonable to assume that the effect on the average fuel consumption is also proportionally reduced. Hence, we apply the same proportional reduction estimated above to the parameters of Equation 1 to produce a relationship between the average size of the lifetime value of the circulation tax and the reduction of fuel consumption within each segment:

$$\%FR = -0.0074 * \ln(T) + 0.0448 \quad [eq. 3]$$

Where *T* is the weighted average value of the lifetime circulation tax.

Context factors influencing the base elasticities

The same context factors posited for the registration tax are considered here and they are also treated in the same fashion to recalibrate all 'base elasticities' (see section 3.2 for details):

- *Effect of income*: as for registration tax, parameters are not corrected.
- *Effect of baseline fuel price*: when fuel price is lower than the EU level, the elasticities are reduced using Equation 4 (below). This assumes that the scalar reduction in responsiveness is of the same magnitude as for the registration tax (i.e. 80% of the base elasticity estimated on European data):

*Elast = Base Elast * [1 + 1.6 *(Fuel Price / Base Fuel price -1)]*

$$Elast = 0.14 *[1+ 1.6 * (Fuel\ price /2 -1)] \quad [eq. 4]$$

Interaction with other measures

The same interactive effects noted for the registration tax are also assumed to be relevant here. They are treated with the same corrections already estimated (see section 3.3 for details):

- *Interaction with registration tax*: Based on COWI (2012), when the two vehicle taxes are applied simultaneously, the sum is multiplied by the scalar 1.3.
- *Interaction with fuel taxation*: It is assumed that a change in fuel taxes brings about the same effect as a change of fuel price and Equation [4] is applied.
- *Interaction with fuel consumption target (emission target)*: the relative reduction of the average fuel consumption induced by the target is computed, it is interpreted like a reduction in fuel price and Equation [4] is used.

Modelling fuel taxation

Assuming that new vehicles registrations are segmented into a certain number of classes, fuel taxation is assumed to generate the same two types of impacts of vehicle taxation within FEPIT:

- A shift of registrations towards lower emissions segments.
- A reduction of average fuel consumption of cars within a specific segment.

Base elasticity values

Impact on the new registrations by segment

According to Klier and Linn (2012), a 1000 Euro increase in the present discounted value of fuel costs leads to a reduction in log registrations by 0.09 in Western Europe.[22] The authors compare this elasticity to their estimate of the impact of a registration tax (log-linear elasticity of 0.56 for France) and of a circulation tax (0.19 for Germany and 0.07 for Sweden, again for a log-linear form). Since we used these elasticities as base values for vehicle taxation measures, it is reasonable to use the value of 0.09 as base value elasticity for the effect of fuel taxation. The elasticity to fuel taxation is therefore lower than to vehicle taxation. This is in line with conclusions of the COWI (2002) study: "the calculations have also shown that fuel taxes are not very effective as an instrument to reduce average CO_2 emissions from new cars".

Taking into account the conversion between Euros and Dollars in PPP, the base elasticity assumed for measuring the impact of an increment of fuel tax on the registrations of new vehicles is 0.09 * 1.1 = 0.1.

Since this elasticity has a small magnitude, the correction for larger vehicles (half of this base value) used for vehicle taxes building on the results of D'Haultfœuille et al. (2012) was not used in the case of fuel taxation: the same elasticity is applied to all segments, in this case.

Impact on the average fuel consumption by segment

As no specific literature was found regarding this aspect, the same approach followed for the quantification of the impact of the circulation tax was adopted here.

If the effect of a fuel tax on the registration mix is lower than the effect of a registration tax (i.e. with a log-linear elasticity 0.1 compared with 0.7), it seems reasonable to assume that also the effect on the average fuel consumption is proportionally reduced. The reduction estimated above to the parameters of Equation 1 was applied here to produce a relationship between the average size of the increment of discounted lifetime fuel expenditure generated by the increased fuel tax and the reduction of fuel consumption within each segment:

$$\%FR = -0.0053 * \ln(T) + 0.0320 \quad [eq. 5]$$

Where *T* is the weighted average value of the lifetime fuel expenditure.

[22] We refer to results presented at page 20 of the paper.

Context factors influencing the base elasticities

The same context factors as for the above measures are considered to affect base elasticities here, as above.

Effect of the average income per capita on the elasticities

As in the case of vehicle taxes (see section 3.2.1 for details), base elasticities are not corrected for income.

Effect of the baseline fuel price on the elasticities

Klier and Linn (2011) found that the impact of fuel price on new vehicle fuel consumption was much larger in the US than in the EU. This is consistent with a lower initial fuel price level: starting from a low level of price (i.e. a low taxation level) the relative change of a given absolute increment of fuel price is larger. Therefore while for vehicle taxes a lower baseline fuel price level leads to lower responsiveness, here, the same logic applies but in the opposite direction: elasticities should be corrected upwards.

Klier and Linn estimate that an increase in average fuel price of 0.265 $/l would improve the average fuel consumption of new vehicles by about 0.33 lge/100 km in the US and 0.05 lge/100km in Europe.[23] Taking into account the average fuel price (0.39 $\$_{2005}$/l in US and 1.00 $€_{2005}$/l in Europe) and the average fuel consumption (about 11.1 lge/100km in US and 15.4 lge/100km in Europe), the elasticity of fuel consumption with respect to fuel prices is about twice as large for the United States as for Europe.

Therefore, base elasticity values should be increased in order to replicate this ratio when comparing the elasticity of fuel consumption to fuel prices in the United States and Europe. In order to get the required responsiveness of fuel consumption the value of the elasticity for the US should be -0.22 instead of -0.1.

The average fuel price in US was about 1 $/litre in comparison to some 2 $/litre in Europe (both values are approximate). Assuming that the difference in elasticity estimated above is explained by this difference in fuel prices, a scalar to increase the base elasticities when the fuel price is different from the EU level can be defined:

- *Elast = Base Elast * [1 – 2.5 *(Fuel Price / Base Fuel price -1)]*
- *Elast = 0.1 *[1- 2.5 * (Fuel price /2 -1)] [eq. 6]*

Equation 6 also takes into account the need to correct the 2005 USD of Klier and Linn with the 2014 USD used in FEPIT.

Interaction with other measures

The assumed interaction between vehicle tax and fuel tax has been explained with reference to the other policy measures (see section 3.3 for details).

[23] We refer to results at page 27 of the report. Original data is expressed in miles per gallon (mpg) rather than lge and are converted here for sake of homogeneity.

The interaction between fuel tax and fuel consumption target is implicitly considered in the calculation: if a target is set and fuel consumption is reduced, the fuel expenditure will be lower and so the effect of the fuel taxation will be smoothed.

Modelling regulatory measures on average fuel economy targets

A fuel economy target identifies the maximum level of average fuel consumption (or CO_2 emissions), computed as corporate sales weighted average on the composition of the new registrations. The target is set for future time horizon and needs to be achieved by manufacturers through technical development or changes in the models mix.

The Global Fuel Economy Initiative (GFEI) has set a target of 4.2 lge/100 km for new vehicle tested fuel economy in the year 2030. Given that the average fuel economy in 2013 was 7.1 lge/100 km, this target corresponds to an average improvement rate of 3.1% per year. As different countries start from very different starting points, reaching the GFEI target can require either more or less ambitious improvement rates. By default, FEPIT allows to consider the following improvement rates:

- allowing to match the GFEI global target fuel economy of 2030
- corresponding to the GFEI average global improvement rate
- calculated as an average of GFEI global target and GFEI average global improvement rate
- other values entered directly by users.

FEPIT computes the reduction rate corresponding to the policy target and, therefore, the average fuel consumption target in the projection year according to the input entered. In other words, the tool assumes that the target is met; its role is to compute the average target fuel economy that should be set at a given year for a certain level of ambition and taking into account the starting conditions.

If other policy measures influencing fleet composition and fuel consumption are activated the tool will compute the effect of these policies on the top of the average improvement rate needed to reach the target.

Validation

Previous sections include information on the sources and the assumptions used to quantify draft elasticity parameters. These draft values have been validated by means of several comparisons between the results of the tool and literature data on the effect of vehicle taxation policies.

This chapter documents the work done to compare literature data on the effects of vehicle taxation on fuel consumption of new registrations. It is based on the application of the FEPIT tool using the elasticities described in previous sections. These comparisons are the basis for a revision of the draft elasticities initially taken into account.

Case studies application from literature

The policies described in the studies listed below have been translated into FEPIT inputs using the following assumptions:

- five classes have been defined in each test (apart from hybrid, plug-in and electric vehicles), grouping the classes used for the definition of the real scheme;
- the value of the taxes before the implementation of the tax/feebate schemes has been estimated according to the available information (extracted from study under consideration or other sources);

- the share of diesel/gasoline vehicles is used to estimate the conversion factor between g CO_2/km and lge/100 km whenever the real scheme is based on CO_2 emissions;
- tax/rebate are converted to Dollars and updated to 2014 using the GDP deflator of the Euro area (e.g. between 2005 and 2014 deflator is 1.15, using World Bank database) and PPP conversion factor between Dollar and Euro (around 1.1 in 2005, 1 $ = 1.1 €).

Study: Klier, T and Linn, J. (2012), Using Vehicle Taxes to Reduce Carbon Dioxide Emissions Rates of New Passenger Vehicles: Evidence from France, Germany, and Sweden

This study reports about the impact of a feebate scheme in France, namely analysing the implementation of the feebate system in 2008. The data have been merged with information from the study D'Haultfœuille et al. (2012), where more detailed figures where provided for the implementation in the tool.

The content of the policy in France in 2008 is the following (as reported in the study): the purchase tax increases in discrete steps from a subsidy of 1,000 euros for vehicles below 100 grams of CO_2 per kilometre (g CO_2/km) to a tax of 2,600 euros for vehicles above 250 g CO_2/km (see Table 3). Prior to 2008, France imposed vehicle purchase taxes largely on the basis of horsepower.

According to the study, 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. According to the modelling analysis, the tax reduces the average emissions rate by 7.95 g CO_2/km in France while the average emissions rates actually declined by 8.70 g CO_2/km between 2007 and 2008. Since the average emission rate in 2007 is about 149 g CO_2/km the impact of the tax corresponds to a reduction of about 5.3%.

Table 3: Amount of the feebate as a function of CO_2 emissions in France

Segment	CO_2/km	Shares of new registrations 2007	Tax/Rebate (in Euro 2007)
A+	<=60	0.00%	-5,000
A-	61- 100	0.00%	-1,000
B	101 - 120	18.40%	-700
C+	121 - 130	10.20%	-200
C- and D	131 - 160	45.40%	0
E+	161- 165	3.20%	200
E-	166 - 200	15.90%	750
F	201 - 250	5.00%	1,600
G	> 250	1.90%	2,600

Source: D'Haultfœuille et al. (2012)

In order to test the tool, the policy has been translated using the following assumptions making reference to the period 2007 - 2008 (see the final estimation in Table 4 and Table 5):

- five classes have been defined, grouping the classes used for the definition of the feebate scheme. The fuel consumption thresholds have been estimated assuming a 70% share of diesel vehicles, as reported in Klier and Linn (2012, figure 1);
- the value of tax/rebate in 2008 has been estimated on the basis of a weighted average of the shares of new registrations reported in D'Haultfœuille et al. (2012, figure 1);

- the value of tax before 2008 has been estimated on the basis of the average emission rate according to the function interpolated from Klier and Linn. (2012, figure 2);
- the shares of new registrations before and after the implementation of the scheme has been estimated from D'Haultfœuille et al. (2012, figure 1);
- the average emission rate of each segment has been estimated in order to comply with the range of the classes and to reproduce the average emission rate of about 149 g CO_2/km in 2007.

Table 4: Estimated amount of the feebate and shares of new registrations in France

Segment	CO_2/km	Shares of new registrations 2007	Tax/Rebate in 2008 (in $ 2015)	Average emission rate (lge/100 km)
ICE <3.85 lge/100km	<=120	18.4%	-886	4.50
ICE 3.85-5 lge/100km	121 - 130	10.2%	-253	4.80
ICE 5-6.2 lge/100km	131 - 165	45.4%	0	5.65
ICE 6.2-7.75 lge/100km	166 - 200	19.1%	832	6.60
ICE >7.75 lge/100km	>200	6.9%	2372	8.70

Source: estimation elaborated on the basis of D'Haultfœuille et al. (2012) data

Table 5: Estimated amount of registration tax by segment before 2008 in France

Segment	CO_2/km	Shares of new registrations 2006*	Tax before 2008 (in $ 2015)	Average emission rate (lge/100 km)*
ICE <3.85 lge/100km	<=120	18.4%	176	4.50
ICE 3.85-5 lge/100km	121 - 130	10.2%	204	4.80
ICE 5-6.2 lge/100km	131 - 165	45.4%	298	5.65
ICE 6.2-7.75 lge/100km	166 - 200	19.1%	426	6.60
ICE >7.75 lge/100km	>200	6.9%	805	8.70

* assumed the same as of 2007, according to D'Haultfœuille et al. (2012), figure 1
Source: estimation elaborated on the basis of D'Haultfœuille et al. (2012), Klier et al. (2012) data

The result of the simulation with FEPIT is a reduction of the average emission rate by 12 g CO_2/km between 2007 and 2008 (about 8.2% reduction), i.e. higher than the reference values (7.95 g CO_2/km, i.e. about 5.3%). This comparison would suggest that draft elasticity parameters are too large.

The same study reports also about the impact of the introduction of annual circulation taxes in Germany that increase linearly with the emissions rate in 2009. The data have been merged with information from the study Adamou et al. (2011), where more detailed figures on registrations in the year 2008 were provided for implementation in the tool.

The content of the policy in Germany is a change from a system based on engine size to a tax that increases linearly with the CO_2 emissions rate. For all vehicles purchased before July 2009, circulation taxes increased linearly with engine capacity, and at a higher rate for diesel fuel vehicles compared to gasoline vehicles. For vehicles purchased in July 2009 or later, registration taxes were the sum of a linear function of engine capacity and a linear function of the CO_2 emissions rate (see Table 6): the base tax is €2 per 100 cc (petrol) and €9.50 per 100 cc (diesel) respectively, while the CO_2 tax is linear at €2 per g/km emitted above 95g/km (cars with CO2 emissions below 95 g/km are exempt from the CO_2 tax component).

Table 6: Vehicle registration tax by CO_2 categories before and after the circulation tax reform in Germany

Segment	2008		2009		
	Tax rate related to engine capacity – gasoline (euro/100 cm^3)	Tax rate related to engine capacity – diesel (euro/100 cm^3)	Tax rate related to engine capacity – gasoline (euro/100 cm^3)	Tax rate related to engine capacity – diesel (euro/100 cm^3)	Tax rate related to CO_2 emission rate, above 95 g/km (euro per g/km)
Euro 3 or higher	6.75	15.44	2.0	9.5	2.0
Euro 2	7.36	16.05	2.0	9.5	2.0
Euro 1	15.13	27.35	2.0	9.5	2.0
Euro 0	21.07	33.29	2.0	9.5	2.0
Other cars	25.36	37.58	2.0	9.5	2.0

Source: estimation elaborated on the basis of Klier (2012) data

According to the study, the circulation tax change in Germany had an effect on vehicle registrations, reducing the average emissions rate by 1.67 g CO_2/km. Since the average emission rate in 2008 is about 156 g CO_2/km the impact of the tax corresponds to a reduction of about 1.1%.

In order to test the policy with the FEPIT tool, the following assumptions has been used (see the final estimation in Table 7 and Table 8):

- five classes have been defined, with a step of 1 lge/100 km (about 25 g CO_2/km) The fuel consumption thresholds have been estimated assuming a 43% share of diesel vehicles, as reported in Klier and Linn (2012, figure 1);
- the value of tax/rebate related to engine capacity in 2008 and 2009 has been estimated on the basis of the estimated engine capacity by segment, resulting from the weighted average of new registrations by engine capacity and fuel consumption (elaboration on the EEA database for the year 2010);
- the shares of new registrations before and after the implementation of the scheme has been estimated from Adamou et al. (2012) and the EEA database ;
- the average emission rate of each segment has been estimated starting from the EEA database in 2010 and adjusted for 2008 in order to comply with the range of the classes and to reproduce the observed improvement of average emission rate by about 1% between 2008 and 2009.

Table 7: Estimated amount of the circulation tax and shares of new registrations in Germany

Segment	CO_2/km	Shares of new registrations 2010	Yearly CO_2 Tax in 2010 (in $ 2015)	Yearly engine capacity Tax in 2010 (in $ 2015)	Average emission rate (lge/100 km)
ICE <4 lge/100km	<=100	0.6%	0	89	3.42
ICE 4 - 5 lge/100km	101 - 125	10.4%	65	93	4.71
ICE 5 - 6 lge/100km	125 - 150	32.8%	121	91	5.57
ICE 6 - 7 lge/100km	151 - 175	30.8%	179	111	6.47

ICE >7 lge/100km	>175	25.3%	299	144	8.16

Source: estimation elaborated on the basis of Klier et al. (2012) data, EEA database

Table 8: Estimated amount of circulation tax before 2009 in Germany

Segment	CO_2/km	Shares of new registrations 2008	Yearly Tax in 2008 (in $ 2015)	Average emission rate (lge/100 km)
ICE <3.85 lge/100km	<=120	0.44%	252	3.52
ICE 3.85-5 lge/100km	121 - 130	7.46%	263	4.84
ICE 5-6.2 lge/100km	131 - 165	45.10%	257	5.72
ICE 6.2-7.75 lge/100km	166 - 200	24.60%	311	6.64
ICE >7.75 lge/100km	>200	22.40%	406	8.55

Source: estimation elaborated on the basis of Klier et al. (2012) data, Adamou et al. (2011) data

The result of the simulation with the tool is a reduction of the average emission rate by 1.6% in addition to the baseline trend between 2008 and 2009 (total reduction is about 4.7%). So again the elasticities seem slightly too large.

Study: Adamou, A., S. Clerides, and T. Zachariadis (2011), Environmental and economic effects of CO_2- based automobile taxes in Germany

This study reports about the impact of the implementation of feebates on newly purchased cars in Germany, simulating with a model different levels of feebate assumed to be applied in 2008.

The content of the policy levels tested is the following: at the beginning of 2008 a feebate scheme is assumed to be introduced. Consumers receive a rebate when purchasing low-CO_2 cars or incur an additional fee when purchasing a high-CO_2 car. The pivot point is set of 140 g CO_2/km. Four different levels of the tax are simulated: 75, 150, 225 and 300 Euros per tonne of CO_2, under the assumption that a car travels 200,000 kilometres throughout its lifetime (see Table 9).

In 2008, Germany was not assumed to impose any vehicle purchase tax.

Table 9: Amount of the feebate schemes tested as a function of CO_2 emissions in Germany

CO_2/km	Shares of new registrations actual 2008	Tax/Rebate (in Euro 2008, 75 Euro/t CO_2)	Tax/Rebate (in Euro 2008, 150 Euro/t CO_2)	Tax/Rebate (in Euro 2008, 225 Euro/t CO_2)	Tax/Rebate (in Euro 2008, 300 Euro/t CO_2)
<=130	7.9%	-375	-750	-1,125	-1,500
131- 160	45.1%	75	150	225	300
161 - 180	24.6%	450	900	1,350	1,800
181 - 200	12.5%	750	1,500	2,250	3,000
> 200	9.9%	1,650	3,300	4,950	6,600

Source: estimation elaborated on the basis of Adamou et al. (2011) data

According to the study, the more stringent the feebate, the higher the fraction of low- and medium-CO_2 cars sold in the market. From 53% of actual total sales in 2008, automobiles with emission levels up to 160 g/km dominate the market in the strong feebate case, reaching 75.3% of total sales. Higher emitting vehicles are faced with a drop in their sales; in the strong feebate case, the share of cars emitting over 200 g/km drops to one-sixth, from 9.9% to 1.7%; and the share of cars emitting between 160 and 180 g/km falls by 60%, from 12.5% to 5%.

In order to test the tool, the policy has been translated using the following assumptions (see the final estimation in Table 10):

- five classes have been defined, according to those reported in the study. The fuel consumption thresholds have been estimated assuming a 43% share of diesel vehicles, as reported for Germany in Klier and Linn (2012, figure 1);
- the shares of new registrations before and after the implementation of the scheme has been taken from Adamou et al. (2012, figure 4);
- the average emission rate of each segment has been estimated in order to comply with the range of the classes and to reproduce the change in new car prices related to the tax/feebate reported in Adamou et al. (2012, figure 2).

Table 10: Estimated amount of the registration tax and shares of new registrations in Germany

Segment	CO_2/km	Shares of new registrations actual 2008	Tax/Rebate (in $ 2015, 75 Euro/t CO_2)	Tax/Rebate (in $ 2015, 150 Euro/t CO_2)	Tax/Rebate (in $ 2015, 225 Euro/t CO_2)	Tax/Rebate (in $ 2015, 300 Euro/t CO_2)	Average emission rate (lge/ 100 km)
ICE <5.2 lge/100km	<=130	7.9%	-474	-949	-1,423	-1,898	4.61
ICE 5.2-6.4 lge/100km	131-160	45.1%	95	190	285	380	5.81
ICE 6.4-7.2 lge/100km	161 - 180	24.6%	569	1,139	1,708	2,277	6.82
ICE 7.2-8.0 lge/100km	181 - 200	12.5%	949	1,898	2,846	3,795	7.62
ICE >8.0 lge/100km	> 200	9.9%	2,087	4,175	6,262	8,349	10.03

Source: estimation elaborated on the basis of Adamou et al. (2011) data

The result of the simulation with FEPIT is analysed in terms of average fuel consumption (lge/ 100 km) under the assumption that the shares reported in the study are applied to the actual average fuel consumption per segment in 2008. The following results are observed and reported in Table 11 and Table 12:

- test with 75 Euro/t CO_2 : the fuel consumption simulated is 6.14 lge/100km instead of 6.38 estimated by the study (-7.0% with respect to actual 2008 value instead of the -3.5% estimated by the study);
- test with 150 Euro/t CO_2 : the fuel consumption simulated is 5.73 lge/100km instead of 6.18 estimated by the study (-13.3% with respect to actual 2008 value instead of the -6.5% estimated by the study);
- test with 225 Euro/t CO_2 : the fuel consumption simulated is 5.44 lge/100km instead of 6.01 estimated by the study (-17.6% with respect to actual 2008 value instead of the -9.0% estimated by the study);
- test with 300 Euro/t CO_2 : the fuel consumption simulated is 5.21 lge/100km instead of 5.85 estimated by the study (-21.2% with respect to actual 2008 value instead of the -11.4% estimated by the study);

- The impacts are therefore larger than the values reported in the study, with stronger reduction in terms of average emission rate.

Table 11: Simulated shares of new registrations and average emission rate in Germany: test with 75 Euro/t CO_2 and 150 Euro/t CO_2

Segment	CO_2/km	Shares new registrations 2008	Test with 75 Euro/t CO_2		Test with 150 Euro/t CO_2	
			Reference	Simulated	Reference	Simulated
ICE <5.2 lge/100km	<=130	7.9%	11.0%	15.1%	14.9%	23.0%
ICE 5.2-6.4 lge/100km	131- 160	45.1%	48.4%	49.9%	50.4%	49.5%
ICE 6.4-7.2 lge/100km	161 - 180	24.6%	23.8%	22.1%	22.3%	19.4%
ICE 7.2-8.0 lge/100km	181 - 200	12.5%	10.4%	8.2%	8.3%	5.9%
ICE >8.0 lge/100km	> 200	9.9%	6.4%	4.8%	4.1%	2.3%
Average emission rate (lge/ 100 km)		**6.61**	**6.38**	**6.14**	**6.18**	**5.73**
			-3.5%	-7.0%	-6.5%	-13.3%

Source: estimation elaborated on the basis of Adamou et al. (2011) data

Table 12: Simulated shares of new registrations and average emission rate in Germany: test with 225 Euro/t CO_2 and 300 Euro/t CO_2

Segment	CO_2/km	Shares new registrations 2008	Test with 225 Euro/t CO_2		Test with 300 Euro/t CO_2	
			Reference	Simulated	Reference	Simulated
ICE <5.2 lge/100km	<=130	7.9%	19.60%	32.09%	25.20%	43.26%
ICE 5.2-6.4 lge/100km	131- 160	45.1%	50.90%	45.04%	50.10%	36.86%
ICE 6.4-7.2 lge/100km	161 - 180	24.6%	20.30%	17.08%	18.00%	15.31%
ICE 7.2-8.0 lge/100km	181 - 200	12.5%	6.60%	4.67%	5.00%	4.03%
ICE >8.0 lge/100km	> 200	9.9%	2.60%	1.11%	1.70%	0.53%
Average emission rate (lge/ 100 km)		**6.61**	**6.01**	**5.44**	**5.85**	**5.21**
		-	-9.0%	-17.6%	-11.4%	-21.2%

Source: estimation elaborated on the basis of Adamou et al. (2011) data

Study: Kok, R. (2013), New car preferences move away from greater size, weight and power: impact of Dutch consumer choices on average CO_2-emissions

This study reports about the impact of a feebate scheme in the Netherlands, namely analysing the implementation of a revision of the vehicle registration tax in 2011. The data have been integrated with information from the study of Kok (2011), where more detailed figures where provided also for the year 2010.

The content of the policy is the following, implemented at the beginning of 2010 and revised in 2011: gasoline and diesel cars up to 110 and 95 gram CO_2/km are exempted from the vehicle registration tax (VRT). The fixed percentage of the pre-tax retail price of a car was set to 27.4% in 2010, while the residual part is based on emissions bands with increasing tax rates per gram CO_2 in each emission band (see Table 13). Furthermore, discounts or surcharges were implemented for gasoline and diesel vehicles[24]. In 2011 the same approach have been implemented, but the pre-tax retail price of a car was set to 19% and the values of tax rate by CO_2 bands were increased as reported in Table 14.

Table 13: VRT emission bands and band size in 2010 in the Netherlands

Emission band	Band size for gasoline vehicles (CO_2/km)	Band size for gasoline vehicles (CO_2/km)	Tax rate in 2010 (in Euro 2010 per gram CO_2/km)
VRT - free	<111	<96	0
Band 1	111 - 180	96 - 155	34
Band 2	181 - 270	156 - 232	126
Band 3	>270	>232	288

Source: Kok (2011)

The study reports that the average CO_2 emissions of new cars have dropped from 136 g/km in 2010 to 126 g/km in 2011 (-7.4%). The analysis assumes that the technological advances resulted in a reduction from 140 g/km in 2009 to 126 g/km in 2011, while the isolated effect of consumer preferences is responsible for a reduction from 185 g/km in 2009 to 179 g/km in 2011.

Table 14: VRT emission bands and band size in 2011 in the Netherlands

Emission band	Band size for gasoline vehicles (CO_2/km)	Band size for gasoline vehicles (CO_2/km)	Tax rate in 2010 (in Euro 2010 per gram CO_2/km)
VRT - free	<111	<96	0
Band 1	111 - 180	96 - 155	61
Band 2	181 - 270	156 - 232	202
Band 3	>270	>232	471

Source: www.belastingdienst.nl

In order to test the tool, the policy has been translated using the following assumptions (see the final estimation in Table 15):

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24 http://www.belastingdienst.nl/wps/wcm/connect/bldcontenten/belastingdienst/individuals/cars/bpm/old_bpm_tariffs/

- five classes have been defined, with reference to the classes used for the definition of the scheme (splitting into two classes the first band). The fuel consumption thresholds have been estimated assuming a 20% share of diesel vehicles, as reported by Kok (2011);
- the value of taxes has been estimated on the basis of the official belastingdienst website[25];
- the shares of new registrations by segment in each year has been estimated from Kok (2011), Kok (2013) and EEA dataset;
- the average emission rate of each segment has been estimated in order to comply with the range of the classes and to reproduce the average emission rate of about 136 g/km in 2010.

Table 15: Estimated amount of the registration tax and shares of new registrations in the Netherlands

Segment	CO_2/km	Shares of new registrations 2010	Tax/Rebate in 2011 (in $ 2015)	Average emission rate (lge/100 km)
ICE <4.6 lge/100km	<=110	24.2%	0	4.2
ICE 4.6-6 lge/100km	111 - 145	41.8%	4,358	5.3
ICE 6-7.5 lge/100km	145 - 180	24.1%	8,261	6.6
ICE 7.5-11.2 lge/100km	181 - 270	9.2%	17,777	7.9
ICE >11.2 lge/100km	>270	0.6%	57,815	11.3

Source: estimation elaborated on the basis of Kok (2011), Kok (2013) data and EEA dataset

The result of the simulation with FEPIT is a reduction of the average emission rate by 16 g CO_2/km between 2010 and 2011 (about 11.8% reduction). Once again these results would suggest that the value of the elasticity parameters is too large.

Study: Mueller, M. G., Haan, P., Scholz, R. W. (2009), How much do incentives affect car purchase? Agent-based microsimulation of consumer choice of new cars

This study investigates about the impact of a hypothetic feebate scheme in Switzerland, assuming the implementation of a vehicle registration tax in 2005.

The content of the policy is the following: the feebate systems is based on an energy-labelling scheme using categories A to G. Very fuel-efficient (A) cars receive a cash incentive, highly inefficient (G) cars pay additional fees. The test under analysis for the tool is a full-feebate scheme, where new cars registered having lowest fuel-efficiency pay a fee of 2,000 euro and Incentives of 2,000 euro for A-labelled new cars are provided.

According to the study, the sales of new cars with average CO_2 emissions below 160 g/km is increased from about 34% in the reference run to 44%, whereas sales of new cars with average CO_2 emissions over 200 g/km are decreased from about 30% to 25%. Furthermore, it is estimated that average CO_2 emissions of new car drops by about 4%.

In order to test the tool, the policy has been translated using the following assumptions (see the final estimation in Table 16):

- five classes have been defined, aggregating the data reported in figure 6 of the paper. The fuel consumption thresholds have been estimated assuming a 29% share of diesel vehicles, as reported in the paper;

[25] http://www.belastingdienst.nl/wps/wcm/connect/bldcontenten/belastingdienst/individuals/cars/bpm/old_bpm_tariffs/

- the value of taxes has been estimated on the basis of the values reported in the study;
- the shares of new registrations by segment in each year has been estimated from figure 6 of the paper;
- the average emission rate of each segment has been estimated in order to comply with the range of the classes and to reproduce the average emission rate of about 188 g/km in 2010.

Table 16: Estimated amount of the tax/rebate and shares of new registrations in Switzerland

Segment	CO_2/km	Shares of new registrations 2005	Tax/Rebate (in $ 2015)	Average emission rate (lge/100 km)
ICE <4.9 lge/100km	<=120	5.0%	-2,045.1	4.7
ICE 4.9-6.5 lge/100km	121 - 160	29.0%	-971.3	6.1
ICE 6.5-8.2 lge/100km	161 – 200	36.5%	113.5	7.9
ICE 8.2-9 lge/100km	200 - 220	14.5%	961.4	8.8
ICE >9 lge/100km	>220	15.0%	2,530.0	10.9

Source: estimation elaborated on the basis of Mueller et al. (2009) data

The result of the simulation with the tool is a reduction of the average emission rate by about 20% (38 g CO_2/km), with a decrease of the registrations of new cars with average CO_2 emissions over 200 g/km from about 30% to 3.7% (see Table 17). These results would suggest to strongly reduce the value of the elasticity parameter.

Table 17: Simulated shares of new registrations and average emission rate in Switzerland

Segment	CO_2/km	Shares new registrations 2005	2006	
			Reference	Simulated
ICE <4.9 lge/100km	<=120	5.0%	8.0%	21.3%
ICE 4.9-6.5 lge/100km	121 - 160	29.0%	36.0%	46.7%
ICE 6.5-8.2 lge/100km	161 – 200	36.5%	31.0%	28.3%
ICE 8.2-9 lge/100km	200 - 220	14.5%	11.0%	3.7%
ICE >9 lge/100km	>220	15.0%	14.0%	0.0%
Average emission rate (lge/ 100 km)		**7.80**	**7.52**	**6.22**
			-3.6%	-20.2%

Source: estimation elaborated on the basis of Mueller et al. (2009) data

Study: Ciccone, A. (2014), Is it all about CO2 emissions? The environmental effects of a tax reform for new vehicles in Norway

This study reports about the impact of the registration tax reform in Norway, namely analysing the implementation of a CO_2-based tax system in 2007.

The content of the policy is the following: the Norwegian government reformed the registration tax system for new vehicles, linking the tax paid at the moment of purchase directly to the potential CO_2 emissions rates of the vehicle. Cars emitting more than 105 grams of CO_2 per km are subject to a progressively increasing tax, while cars releasing less than this actually enjoy a deduction in the tax levied on the other components of the total tax, i.e. weight and engine power (see Table 18).

Table 18: Vehicle registration tax by CO_2 categories before and after the tax reform for new vehicles in Norway

Emission band (CO_2/km)	Tax rate in 2006 (in Euro 2012)	Tax rate in 2007 (in Euro 2012)	Tax rate difference (in Euro 2012)
<120	8,388	6,427	-1,960
121 - 140	11,341	8,925	-2,417
141 - 180	15,102	13,512	-1,590
181 - 250	23,495	26,215	2,720
>250	55,836	73,720	17,884

Source: estimation elaborated on the basis of Ciccone (2014) data (average exchange rate 2012: 1 NOK = 0.13 euro)

According to the study, the average CO_2 intensity of new vehicles was reduced between 6 and 8 gCO_2/km in a year where the average CO_2 intensity was about 160 gCO_2/km (about 4% to 5% decrease), which is almost half of the overall reduction observed when including supply effects. This reduction is the result of a 12% points drop in the share of highly polluting cars (more than 180 g CO_2/Km) and of an increase of about 23% points in the market share of diesel cars.

In order to test the tool, the policy has been translated using the following assumptions (see the final estimation in Table 19):

- five classes have been defined, according to those reported in the study (Ciccone 2014, table 3). The fuel consumption thresholds have been estimated assuming a 49% share of diesel vehicles, as reported by Ciccone (2014, figure3) for the year 2006;
- the value of taxes has been estimated on the basis of the values reported in the study;
- the shares of new registrations by segment in each year has been estimated from figure 2 of the paper;
- the average emission rate of each segment has been estimated in order to comply with the range of the classes and to reproduce the average emission rate of about 160 gCO_2/km in 2006.

Table 19: Estimated amount of the registration tax and shares of new registrations in Norway

Segment	CO_2/km	Shares of new registrations 2006	Registration tax in 2006 (in $ 2015)	Registration tax in 2007 (in $ 2015)	Average emission rate (lge/100 km)
ICE <4.8 lge/100km	<=120	1.0%	9,226	7,070	4.6
ICE 4.8-5.6 lge/100km	121 - 140	17.0%	12,475	9,817	5.4
ICE 5.6-7.2 lge/100km	141 – 180	47.0%	16,612	14,863	6.1
ICE 7.2-9.9 lge/100km	181 - 250	34.0%	25,844	28,836	7.5
ICE >9.9 lge/100km	>250	1.0%	61,420	81,092	10.1

Source: estimation elaborated on the basis of Ciccone (2014) data

The result of the simulation with FEPIT is a reduction of the average emission rate by about 17% (about 28 g CO_2/km), with a decrease of the registrations of new cars with average CO_2 emissions over 180 g/km to 0% (see Table 20). These results would suggest to strongly reduce the value of the elasticity parameter.

Table 20: Simulated shares of new registrations and average emission rate in Norway

Segment	CO_2/km	Shares new registrations 2006	2007	
			Reference	Simulated
ICE <4.8 lge/100km	<=120	1.0%	2.0%	2.2%
ICE 4.8-5.6 lge/100km	121 - 140	17.0%	24.0%	48.9%
ICE 5.6-7.2 lge/100km	141 – 180	47.0%	52.0%	48.9%
ICE 7.2-9.9 lge/100km	181 - 250	34.0%	21.5%	0.0%
ICE >9.9 lge/100km	>250	1.0%	0.5%	0.0%
Average emission rate (lge/ 100 km)		**6.48**	**6.22**	**5.35**
			-4.0%	-17.5%

Source: estimation elaborated on the basis of Ciccone (2014) data

Study: Huse, C. and Lucinda, C. (2014), The Market Impact and the Cost of Environmental Policy: evidence from the Swedish "Green Car" Rebate

This study reports about the effects of the Swedish Green Car Rebate, implemented in 2008.

The content of the policy consisted of a rebate of about 10,000 SEK (about 1,700 $ in 2014 €) paid to private individuals purchasing new environmentally friendly – or green – cars. The GCR defined a green car according to which fuels are able to operate on and on how much CO_2it emits: while petrol and diesel cars were considered green cars provided they emitted no more than 120 g CO_2/km, those able to run on alternative fuels (ethanol, electricity and gas – which we call CNG hereafter) were given a more lenient treatment roughly equivalent to 220 g CO_2/km. The study analysis the effects of the current GCR scheme as well as a scheme where the same limit of 120 g CO_2/km is applied to all vehicles (see Table 21).

According to the study, FFVs[26] were the main gainers following the GCR reaching about 15% of registrations in 2008, while CNG and electric vehicles never commanded more than 1% of the market. The growth in the FFV share was, to a large extent, at the expense of high-emission regular vehicles, which commanded a market share of 77.7% in 2008 down from a 94.7% in 2006. Although low-emission regular vehicles also gained market share, this was much lower than the gain experienced by FFVs. Simulating the case of the GCR treating regular and alternative fuels symmetrically, low-emission vehicles would be the main gainers with an increase of 1.57 and 0.589 % for petrol and diesel vehicles respectively. However, an impact is observed anyway on the share of FFVs with respect to a scenario without the policy: it suggests that a substantial share of consumers would have purchased FFVs regardless of the GCR, likely due to the potentially lower operating costs provided by such technology.

Table 21: Market shares and rebate by segment and scenario in Sweden

Segment	No policy	GCR symmetric
Market shares (%)		
Petrol <=120 g CO_2/km	4.8%	8.2%
Diesel <=120 g CO_2/km	2.0%	4.2%
Petrol >120 g CO_2/km	55.6%	49.5%
Diesel >120 g CO_2/km	25.3%	24.2%
FFVs <220 g CO_2/km	12.1%	13.7%

[26] cars able to operate on ethanol (and on petrol)

Hybrid electric/CNG	0.2%	0.2%
Rebate ($ 2014)		
Petrol <=120 g CO_2/km	-	1,770
Diesel <=120 g CO_2/km	-	1,770
FFVs <220 g CO_2/km	-	-

Source: estimation elaborated on the basis of Huse et al.(2014) data

In order to test the tool, the policy has been translated using the following assumptions:

- Only three classes have been defined, according to those reported in the study (Huse et al. 2014, figure 2). The fuel consumption thresholds have been estimated assuming a 27% share of diesel vehicles, as reported by the study;
- the value of rebates has been estimated on the basis of the values reported in the study;
- the shares of new registrations by segment in each year has been estimated from figure 2 of the paper;
- the average emission rate of each segment has been estimated according to the data reported in table 2 of the paper.

The simulation with FEPIT is related to the GCR scheme treating regular and alternative fuels symmetrically. The result shows that the registrations of low-emission regular vehicles (CO_2 emissions below 120 g/km) and FFVs cover respectively about 23% and 12% (the difference with respect to the study is therefore of 11% and -2%, see Table 22)). Also these comparisons speak for significantly too large elasticities.

Table 22: Simulated shares of new registrations and average emission rate in Sweden

Segment	CO_2/km	No policy	GCR symmetric	
			Reference	Simulated
ICE <4.9 lge/100km	<=120 g CO_2/km	6.8%	12.4%	23.3%
ICE >4.9 lge/100km	>120 g CO_2/km	80.9%	73.7%	64.0%
FFVs	FFVs <220 g CO_2/km	12.1%	13.7%	12.1%
Hybrid electric/CNG	-	0.2%	0.2%	0.6%
Average emission rate (lge/ 100 km)		**8.07**	**7.82**	**7.61**
			-3.0%	-5.6%

Source: estimation elaborated on the basis of Huse et al.(2014) data

Study: Bunch, D.S., Greene, D.L., Lipman, T., Martin, E., Shaheen, S. (2011), Potential Design, Implementation, and Benefits of a Feebate Program for New Passenger Vehicles in California

This study reports about the potential design, implementation, and benefits of a feebate program for new light-duty vehicles in California (US).

Several options are tested with a modelling tool, compared with a reference case assuming a continued constant (linear) reduction of 2% per year of new vehicle CO_2 emission rate. Vehicle purchase taxes are assumed to be null in the reference case. For testing the tool the following cases are analysed: a feebate system implemented only in California with rate of $20/g/mi and $30/g/mi; the option with $20/g/mi have been tested also under different levels of fuel price (high oil price with an increase of 1$/gallon and low oil price with a slight decrease of 1$/gallon with respect to the reference). The content of the policy levels tested is implemented at the year 2011 and simulated until 2025.

According to the study, the $20/g/mi rate reduces average vehicle emissions by about 12 g/mi from 2011 to 2015, while the $30 rate reduces emissions by about 18 g/mi over the same period. In comparison with the initial average vehicle emissions of 250 g/mi, the reduction observed in the study are about 4.8% and 7.2% respectively. When simulating the cases including the effect of fuel prices, the emissions reduction is around 13 g/mi in 2015 with high fuel price and about 9 g/mi with low fuel price (about 5.2% and 3.6% reduction in comparison with initial average vehicle emissions).

In order to test the tool, the policy has been translated using the following assumptions (see the final estimation in Table 23):

- the shares of new registrations by segment in each year has been estimated from data on Fuel Economy Performance released from U.S. Department Of Transportation (2014), combined with data on Hybrid Electric Vehicle and Plug-in Electric Vehicle in U.S. (U.S. Department Of Energy, 2014[27]);
- five classes have been defined, following the analysis of data on new registrations. The fuel consumption thresholds have been estimated assuming a 3% share of diesel vehicles;
- the average emission rate of each segment has been estimated in order to comply with the range of the classes and to reproduce an average emission rate of about 9.7 lge/100km[28] in 2010;
- the value of taxes has been estimated on the basis of the values reported in the study in $g/mi and applied to the average emission rate by segment;
- the reference case (baseline) is estimated assuming a reduction of 2% per year of new vehicle average fuel consumption;
- hybrid electric vehicles are considered exempted from the tax.

Table 23: Estimated amount of the registration tax and shares of new registrations at the base year in California (US)

Segment	Shares of new registrations 2010	Shares of new registrations 2005 (past year)	Tax (in $ 2015) with $20/g/mi	Average emission rate in 2010 (lge/100 km)
Hybrid electric	2.4%	1.2%	-	4.5
ICE <4.9 lge/100km	4.8%	2.6%	1,752	6.0
ICE 4.9-6.5 lge/100km	13.2%	10.9%	2,046	7.0
ICE 6.5-8.2 lge/100km	21.6%	31.1%	2,341	8.0
ICE 8.2-9 lge/100km	14.0%	7.8%	2,635	9.0
ICE >9 lge/100km	44.1%	46.3%	3,592	12.2

Source: estimation elaborated on the basis of Bunch et al. (2011) data, U.S. Department Of Transportation (2014) data, and U.S. Department Of Energy (2014) data

The simulations with FEPIT are implemented starting from data on the market shares of new vehicles in US; the following results are observed (see Table 24):

- test with $20/g/mi rate: the average new vehicle emissions simulated is reduced by about 7.5% instead of 4.8% estimated by the study;

[27] http://www.afdc.energy.gov/data/#
[28] normalized to the NEDC test cycle

- test with $30/g/mi rate: the average new vehicle emissions simulated is reduced by about 10.3% instead of 7.2% estimated by the study;
- test with $20/g/mi rate, high fuel price: the average new vehicle emissions simulated is reduced by about 26.6% instead of 5.2% estimated by the study;
- test with $20/g/mi rate, low fuel price: the average new vehicle emissions simulated is reduced by about 3.0% instead of 3.6% estimated by the study.

The impacts are therefore generally larger than the values reported in the study (except for the low fuel price test), with stronger reduction in terms of average emission rate. Therefore, a reduction of the elasticity parameters for registration taxes and fuel price is suggested, together with a check of the parameter related to initial level of fuel price.

Table 24: Simulated average emission rate in the test related to registration tax in California (US)

	Reference case	Test with $20/g/mi rate		Test with $30/g/mi rate	
		Reference	Simulated	Reference	Simulated
Average emission rate	**9.5**	**[9.0]***	**8.7**	**[8.8] ***	**8.5**
% variation	-	-4.8%	-7.5%	-7.2%	-10.3%
Average emission rate - High fuel price	**9.5**	**[9.0] ***	**6.9**		
% variation	-	-5.2%	-26.6%		
Average emission rate - Low fuel price	**9.5**	**[9.1] ***	**9.2**		
% variation		-3.6%	-3.0%		

*estimation with the tool, value not reported in the study
Source: estimation elaborated on the basis of Adamou et al. (2011) data

Data: EEA Monitoring of CO2 emissions from passenger cars

Data from the EEA dataset related to CO_2 emissions of new vehicles registration have been used to analyse the impact of the annual circulation tax reform in Greece in 2011. The data have been merged with information from the study Adamou et al. (2011), where more detailed figures on registrations in the year 2008 were provided to enrich the implementation in the tool.

The content of the policy in Greece is a change from a circulation tax system based on engine size to a tax that since 1 January 2011 increases with the CO_2 emissions rate (see Table 25 and Table 26): rates vary from €0.90 per gram of CO_2 emitted (101 – 120 g/km) to €3.40 per gram (above 250 g/km). Cars with emissions up to 100g/Km are exempt.

Table 25: Vehicle circulation tax by CO_2 categories since 2011 in Greece

Emission band (CO_2/km)	Tax rate in 2011 (euro per g/km)
<=100	0.0
101-120	0.9
121-140	1.1
141-160	1.7
161-180	2.3
181-200	2.6
201-250	2.8
>250	3.4

Source: ACEA TAX GUIDE (2014)

Table 26: Vehicle circulation tax by engine size until 2011 in Greece

Engine capacity (cc)	Annual Tax rate before 2011 (euro)
0-300	22
301-785	55
786-1,071	120
1,072-1,357	135
1,358-1,548	240
1,549-1,738	265
1,739-1,928	300
1,929-2,357	660
2,358-3,000	880
3,001-4,000	1,100
4,001	1,320

Source: ACEA TAX GUIDE (2014)

According to the observed data an effect on vehicle registrations is observed between 2010 and 2011, with a reduction of the average fuel consumption by about 8% (from 6.22 lge/100 km to 5.72 lge/100 km).

In order to test the tool, the policy has been translated using the following assumptions (see the final estimation in Table 27):

- the shares of new registrations by segment in each year has been estimated from the EEA dataset and the study Adamou et al. (2011) for the year 2008;
- five classes have been defined, following the analysis of data on new registrations. The fuel consumption thresholds have been estimated assuming a 4% share of diesel vehicles, according to ACEA data in 2008;
- the average emission rate of each segment has been estimated starting from the EEA dataset and adjusted in 2008 to comply with the range of the classes and to reproduce an average emission rate of about 159.5 grams CO_2 per kilometre;
- the value of taxes in 2011 has been estimated on the basis of the values reported in the study in euro per gCO_2/km and applied to the average emission rate by segment;
- the value of the taxes until 2011 has been estimated on the basis of the values reported in the ACEA TAX GUIDE (2014) depending on capacity and applied to the average capacity by segment (estimated from the EEA dataset at the year 2010).

Table 27: Estimated amount of the circulation tax and shares of new registrations in Greece

Segment	Shares of new registrations 2010	Shares of new registrations 2008 (past year)	Tax in 2011 (in \$ 2015)	Tax until 2011 (in \$ 2015)	Average emission rate in 2010 (lge/100 km)
ICE <4 lge/100km	0.4%	0.3%	0.0	51	3.9
ICE 4-5 lge/100km	9.0%	6.7%	110.0	51	4.7
ICE 5-6 lge/100km	44.4%	34.7%	158.2	51	5.5
ICE 6-7 lge/100km	28.8%	19.4%	285.4	51	6.5
ICE >7 lge/100km	17.4%	38.8%	552.3	123	8.3

Source: estimation elaborated on the basis of EEA dataset, ACEA TAX GUIDE (2014), Adamou et al. (2011) data

The result of the simulation with FEPIT is a reduction of the average fuel consumption by about 10% (from 6.22 lge/100 km to 5.62 lge/100 km, see Table 28). These outcomes compare quite well with the reference data even if the impact is slightly exaggerated.

Table 28: Simulated shares of new registrations and average emission rate in Greece

Segment	Shares new registrations 2010	Shares new registrations 2011	
		Reference	Simulated
ICE <4 lge/100km	0.4%	3.6%	1.8%
ICE 4-5 lge/100km	9.0%	19.9%	18.7%
ICE 5-6 lge/100km	44.4%	46.0%	51.4%
ICE 6-7 lge/100km	28.8%	21.6%	23.4%
ICE >7 lge/100km	17.4%	8.9%	4.7%
Average emission rate (lge/ 100 km)	**6.22**	**5.72**	**5.62**
		-8.1%	-9.5%

Source: estimation elaborated on the basis of EEA dataset

Study: Hennessy, H., Tol, R.S.J. (2010), The impact of tax reform on new car purchases in Ireland

This study reports about the impact of tax reform on new car purchases in Ireland, implemented in 2008. The reform affects both registration (VRT) and circulation tax (motor tax, MT). The data have been merged with information from the study Rogan et al. (2011), where more detailed figures where provided for the implementation in the tool.

The content of the policy in Ireland is the following, implemented since July 1st 2008 (see Table 29): the purchase tax increases in discrete steps from a subsidy of 1,000 euros for vehicles below 100 grams of CO_2 per kilometre (g CO_2/km) to a tax of 2,600 euros for vehicles above 250 g CO_2/km. Prior to 2008, Ireland imposed vehicle purchase taxes largely on the basis of horsepower.

Table 29: Amount of the taxes before and after the reform in Ireland

Segment (range CO_2/km)	Vehicle Registration Tax (% of OMSP) before 2008	Vehicle Registration Tax (% of OMSP) after 2008	Motor Tax (in Euro 2008) before 2008	Motor Tax (in Euro 2008) after 2008
<=110	22.5%	14.0%	286	104
111- 120	22.5%	14.0%	286	104
121 - 130	25.0%	16.0%	357	156
131 - 140	25.0%	16.0%	357	156
141 - 155	25.0%	20.0%	357	302
156- 170	25.0%	24.0%	471	447
171 - 190	30.0%	28.0%	582	630
191 - 225	30.0%	32.0%	784	1,050
> 225	30.0%	36.0%	1,566	2,100

Source: estimation elaborated on the basis of Hennessy et al. (2010) data, Rogan et al. (2011) data

According to the study, the tax reform in Ireland had a large impact on vehicle registrations by segment comparing 2009 to 2007:

- Lower emitting bands (below 140 g/km) increased their share from 18% to 55%;
- Medium emitting bands (141 to 155 g/km) decreased their share from 23% to 21%;
- Higher emitting bands (above 155) decreased their share from 59% to 23%.

Furthermore, the average specific CO2 emissions for new private cars have fallen from 164 g CO2/km in 2007 to 145.5 g CO2/km in 2009 (corresponding to a reduction of about 11% in two years).

In order to test the tool, the policy has been translated using the following assumptions (see the final estimation in Table 30):

- five classes have been defined, grouping the classes used for the definition of the registration and motor tax. The fuel consumption thresholds have been estimated assuming a 28% share of diesel vehicles;
- two policies have been applied at the same time: registration tax and circulation tax;
- the value of taxes before and after 2008 has been estimated on the basis of a weighted average emission rate of segment and under assumptions on the OMSP for each segment with reference to Hennessy et al. (2010), Rogan et al. (2011);
- the shares of new registrations before and after the implementation of the scheme has been estimated from Rogan et al. (2011, table 5);
- the average emission rate of each segment has been estimated in order to comply with the range of the classes and to reproduce the average emission rate of about 164 g CO_2/km in 2007.

Table 30: Estimated amount of the tax and shares of new registrations in Ireland

Segment	Shares of new registrations 2007	Vehicle Registration Tax (in $ 2015)		Yearly Motor Tax (in $ 2015)		Average emission rate (lge/ 100 km)
		before 2008	after 2008	before 2008	after 2008	
ICE <4.9 lge/100km	1.5%	2,460	1,531	362	132	4.7
ICE 4.9-5.7 lge/100km	16.3%	3,163	2,024	452	197	5.5
ICE 5.7-6.3 lge/100km	23.4%	3,163	2,530	452	382	6.1
ICE 6.3-7.8 lge/100km	46.3%	4,157	3,934	661	674	6.9
ICE >7.8 lge/100km	12.6%	8,220	9,189	1,320	1,769	9.2

Source: estimation elaborated on the basis of Hennessy et al. (2010) data, Rogan et al. (2011) data

The result of the simulation with FEPIT is a reduction of the average emission rate by about 15.4% between 2007 and 2009 (reduction of about 25 g CO_2/km), while the following changes are simulated in terms of vehicle shares: lower emitting bands (below 140 g/km) increase from 18% to 60%, medium emitting bands (141 to 155 g/km) increase from 23% to 28%, higher emitting bands (above 155) decreased their share from 59% to 11% (see Table 31). This result would suggest reducing the value of the elasticity parameters for circulation and registration taxes.

Table 31: Simulated shares of new registrations and average emission rate in Ireland

Segment	CO_2/km	Shares new registrations 2007	Shares new registrations 2009	
			Reference	Simulated

ICE <4.9 lge/100km	<=120	1.5%	10.9%	5.8%
ICE 4.9-5.7 lge/100km	121 - 140	16.3%	43.9%	54.3%
ICE 5.7-6.3 lge/100km	141 – 155	23.4%	21.2%	28.6%
ICE 6.3-7.8 lge/100km	156 – 190	46.3%	20.6%	11.4%
ICE >7.8 lge/100km	>191	12.6%	3.3%	0.0%
Average emission rate (lge/ 100 km)		**6.74**	**5.95**	**5.71**
			-11.7%	-15.4%

Source: estimation elaborated on the basis of Hennessy et al. (2010) data, Rogan et al. (2011) data

Murray, J., (2011), Car CO2 taxation and its impact on the British car fleet

This study[29] reports about the impact of UK car tax policy, namely the reform of Vehicle Excise Duty (VED) which was moved to a CO_2 basis in 2001 and revised and rationalised in 2010.

The content of the policy in UK is the following, with reference to the reform implemented in 2010 (see **Table** 32): cars over 166 g/km CO_2 have pay an increased rate of VED, while cars below 121 g/km CO_2 are exempt for the first year. VED ranges from 20 £ per year (for cars between 101 and 110 g/km CO_2) and 435 £ per year (for cars above 255 g/km CO_2). For the first year a higher rate of VED was introduced in 2010 to specifically influence new car buyers choice on a CO_2 basis: first year VED ranges from 110 £ per year (for cars between 131 and 140 g/km CO_2) and 950 £ per year (for cars above 255 g/km CO_2).

It is also underlined that Fuel prices in UK are amongst highest in Europe and it is reported that between 2009 and 2009 total fuel price increased by about 0.20 £ /l.

Table 32: Amount of the taxes before and after the reform in 2010 in UK

Segment (range CO_2/km)	VED band before 2010	VED before 2010 (£ per year)	VED band 2010	Standard VED 2010 (£ per year)	First year VED 2010 (£ per year)
<100	A	65	A	0	0
101-110	B	75	B	20	0
111-120	B	75	C	30	0
121-130	C	105	D	90	0
131-140	C	105	E	110	110
141-150	C	105	F	125	125
151-165	D	125	G	155	155
166-175	D	125	H	180	250
176-185	E	145	I	200	300
186-200	E	145	J	235	425
201-225	F	190	K	245	550
226-255	G	210	L	425	750
>255	G	210	M	435	950

Source: Murray (2011)

According to the study, the impact of the elements mentioned above (tax reform, fuel price increase, new car fuel consumption label, but also economic situation and recent recession) is

[29] Only a presentation of the study was found rather than the study itself

observed in terms of reduction of the new car CO_2 emissions rate which is about 144 g/km in 2010 (compared to about 149 g/km in 2009, i.e. about 3% reduction). Average CO_2 emissions have reduced in each car segment and demand for lower CO_2 cars has been encouraged: cars below 125 g/km account in 2010 for about 36% of new registrations (from about 29% in 2009).

In order to test the tool, the policy has been translated using the following assumptions (see the final estimation in Table 33):

- five classes have been defined, grouping the classes used for the definition of the Vehicle Excise Duty. The fuel consumption thresholds have been estimated assuming a 46% share of diesel vehicles, as reported in the study;
- two policies have been applied at the same time: registration tax and circulation tax, in order to take into account that different values of VED apply in the first year (simulated as a registration tax);
- the value of taxes before and after 2010 has been estimated on the basis of a weighted average emission rate of each segment;
- the shares of new registrations has been estimated from Murray (2011) and the EEA dataset;
- the average emission rate of each segment has been estimated from the EEA dataset at 2010 and adjusted in previous years in order to comply with the range of the classes and to reproduce the average emission rate of about 149 g/km in 2009.

Table 33: Estimated amount of the tax and shares of new registrations in UK

Segment	Shares of new registrations 2009	Vehicle Registration Tax (in $ 2015)		Yearly Motor Tax (in $ 2015)		Average emission rate (lge/ 100 km)
		before 2010	after 2010	before 2010	after 2010	
Hybrid electric	0.8%	0.0	0.0	0.0	0.0	4.5
ICE <4 lge/100km	1.5%	0.0	0.0	97.5	0.0	3.9
ICE 4-5 lge/100km	16.3%	0.0	-30.0	112.5	30.0	4.7
ICE 5-6 lge/100km	23.4%	0.0	0.0	157.5	165.0	5.5
ICE 6-7 lge/100km	46.3%	0.0	0.0	187.5	232.5	6.5
ICE >7 lge/100km	12.6%	0.0	457.4	285.0	367.4	8.3

Source: estimation elaborated on the basis of Murray (2011) data, EEA dataset

The simulation with FEPIT is implemented using at the same time the policies related to registration tax (first year VED), circulation tax (standard VED) and fuel tax. The result is a reduction of the average emission rate by about 3.7% between 2009 and 2010 (reduction of about 5.4 g CO_2/km), while the following changes are simulated in terms of vehicle shares: lower emitting bands (below 125 g/km) increase from 29% to 39% (see Table 34). The outcome is comparable with reference values, even if there is some overestimation.

Table 34: Simulated shares of new registrations and average emission rate in UK

Segment	CO_2/km	Shares new registrations 2009	Shares new registrations 2010	
			Reference	Simulated
Hybrid electric	-	0.8%	1.1%	3.8%
ICE <4 lge/100km	<=120	1.5%	2.3%	0.9%
ICE 4-5 lge/100km	121 - 140	16.3%	33.6%	37.4%
ICE 5-6 lge/100km	141 – 155	23.4%	28.7%	31.7%

ICE 6-7 lge/100km	156 – 190	46.3%	19.6%	17.4%
ICE >7 lge/100km	>191	12.6%	14.6%	8.6%
Average emission rate (lge/ 100 km)		**5.94**	**5.77**	**5.73**
			-3.0%	-3.7%

Source: estimation elaborated on the basis of Murray (2011) data

Study: Ryan, L., Ferreira, S., Convery, F. (2009), The impact of fiscal and other measures on new passenger car sales and CO2 emissions intensity: evidence from Europe

This study examines the impact of national fiscal measures in the EU (EU15) on passenger car sales and the CO_2 emissions intensity of the new car fleet over the period 1995–2004. The analysis takes into account also the impact of fuel price on vehicle circulation and the average CO_2 emissions of the car fleet.

It is reported that the short run petrol price elasticity is −0.03 with respect to CO_2 fleet emissions intensity, meaning that an increase in petrol prices of 10% could lead to a reduction in CO_2 emissions of approximately 0.5 g per km on average for the fleet and up to nearly 2.8 g per km in the longer term (taking 160 g CO_2 per km as an approximate average for the current fleet it is about 0.3% in the short term and 1.8% in the longer term).

In order to test the tool, the policy has been translated using the following assumptions:

- five classes have been defined, using elaboration of data from the EEA dataset for EU15 for the year 2005. The fuel consumption thresholds have been estimated assuming a 50% share of diesel vehicles;
- fuel tax policy has been implemented in order to simulate an increase of total fuel price by 10%;
- the shares of new registrations and average emission rate of each segment in 2005 has been estimated from the EEA dataset, adjusted in order to reproduce the average emission rate of about 160 g CO_2/km.

The result of the simulation with FEPIT is a reduction of the average emission rate by about 3.2% between 2005 and 2020 (reduction of about 5 g CO_2/km), while the following changes are simulated in terms of vehicle shares: lower emitting cars (below 122 g/km) increase from 11% to 16% and higher emitting cars (above 171 g/km) decrease from 20% to 16% (see **Error! Not a valid bookmark self-reference.**). This result, compared to the longer term impact reported in the study, would suggest reducing slightly the value of the elasticity parameters for fuel taxes.

Table 35: Simulated shares of new registrations and average emission rate in EU15

Segment	Shares new registrations 2005	Shares new registrations 2020	
		Reference	Simulated
ICE <4 lge/100km	0.1%	n.a.	1.2%
ICE 4-5 lge/100km	11.1%	n.a.	15.1%
ICE 5-6 lge/100km	36.1%	n.a.	36.9%
ICE 6-7 lge/100km	33.1%	n.a.	30.4%
ICE >7 lge/100km	19.5%	n.a.	16.4%
Average emission rate (lge/ 100 km)	**6.36**	**6.25**	**6.16**

		-1.8%	-3.2%

Source: estimation elaborated on the basis of Ryan et al. (2009) data

Study: Busse, M. R., C. R. Knittel, and F. Zettelmeyer (2013). Are consumers myopic? Evidence from new and used car purchases

This study estimates the effect of gasoline prices on short-run equilibrium prices of cars of different fuel economies in the US. The analysis takes into account also the impact on new vehicle sales by fuel consumption band.

It is reported that when gasoline price increase by 1 $/gallon the amount of cars sold in the higher fuel consumption quartile is reduced by 27%; in the lower fuel consumption quartile the impact is an increase by 10.8%. Using data from Ward's national sales, the shares reported in the following table are observed.

Table 36: Effect of fuel price on new registrations market shares in the US

Segment (range lge/100 km)	Average lge/100 km	Reference share in 2008	Effect of fuel price on share in 2008
<9.3	8.0	30%	35%
9.3 – 10.9	10.1	26%	26%
10.9 – 12.5	11.8	21%	21%
>12.5	14.2	23%	18%

Source: estimation elaborated on the basis of Busse et al. (2013) data

In order to test the tool, the policy has been translated using the following assumptions:

- the shares of new registrations in each year has been estimated from data on Fuel Economy Performance released from U.S. Department Of Transportation (2014), combined with data on Hybrid Electric Vehicle and Plug-in Electric Vehicle in U.S. (U.S. Department Of Energy, 2014[30]);
- Apart from hybrid vehicles, five classes have been defined, following the analysis of data on new registrations and the value reported in the study. The fuel consumption thresholds have been estimated assuming a 3% share of diesel vehicles;
- A fuel tax policy has been implemented in order to simulate an increase of total fuel price by 1 $/gallon;
- the average emission rate of each segment has been estimated from data reported in the study.

The result of the simulation with FEPIT is a reduction of the average fuel consumption by about 13.6% (reduction of about 1.5 lge/100 km), while the following changes are simulated in terms of vehicle shares: higher fuel consumption bands (above 12.5) decreased their share from 23% to 9.5%, while lower fuel consumption bands (below 9.3 lge/100 km) increase from 30% to 48% (see **Table** 37). Also this comparison leads to the conclusion the draft elasticity parameters for fuel taxes are too large.

Table 37: Simulated shares of new registrations and average emission rate in the US

Segment	Shares new registrations 2008	Effect of fuel price on share in 2008	
		Reference	Simulated

[30] http://www.afdc.energy.gov/data/#

Hybrid electric	2.4%	2.9%	9.5%
ICE <8 lge/100km	4.1%	4.9%	10.2%
ICE 8-9.3 lge/100km	23.2%	27.5%	28.5%
ICE 9.3-10.9 lge/100km	26.2%	25.5%	26.7%
ICE 10.9-12.5 lge/100km	20.9%	21.1%	15.7%
ICE >12.5 lge/100km	23.2%	18.1%	9.5%
Average emission rate (lge/ 100 km)	**10.7**	**10.3**	**9.2**
		-3.2%	-13.6%

Source: estimation elaborated on the basis of Busse et al. (2013)

Study: Mock, P. and Yang, Z. (2014). Driving electrification: a global comparison of fiscal incentive policy for electric vehicles

This study evaluates the response to fiscal incentives in 2013 to incentivize the purchase of plug-in electric vehicles in major vehicle markets around the world. In particular, data related to the Netherlands, France, Sweden and United Kingdom have been used for the validation of FEPIT. The data has been merged with information taken from the EEA dataset related to CO_2 emissions of new vehicles registration. Furthermore, information on circulation tax for the conventionally fuelled vehicles has been collected to complement the inputs for the FEPIT tool.

Table 38: Amount of the incentives and share of new registrations in the Netherlands, France, Sweden and United Kingdom

Country	Segment	Shares of new registrations			Rebate ($)
		2012	2013	2014	
The Netherlands	Battery electric	0.16%	0.63%	0.77%	5000[31]
	Hybrid Plug-in electric	0.86%	4.77%	2.56%	5000[31]
France	Battery electric	0.29%	0.50%	0.60%	7000
	Hybrid Plug-in electric	0.00%	0.05%	0.11%	4000
Sweden	Battery electric	0.10%	0.16%	0.41%	4800
	Hybrid Plug-in electric	0.25%	0.41%	1.13%	4800
United Kingdom	Battery electric	0.07%	0.12%	0.30%	7499
	Hybrid Plug-in electric	0.00%	0.05%	0.32%	7499

Source: estimation elaborated on the basis of Mock et al. (2014), EEA dataset

In order to test the tool, the policy has been translated using the following assumptions:

- the shares of new registrations in each year has been estimated from data of the EEA dataset related to CO_2 emissions of new vehicles registration (years 2010 to 2014), combined with data on Electric Vehicles and Plug-in Electric Vehicle registrations from ACEA (2015);
- Apart from electric vehicles, five classes have been defined, following the analysis of data on new registrations of the EEA dataset. Diesel shares have been estimated from ACEA data;
- the average emission rate of each segment has been estimated from data reported in the EEA dataset.

The result of the simulation with FEPIT is reported in the following tables by country.

The following considerations can be derived looking at the results:

[31] Incentives in selected cities

- the shares of new registrations of alternative vehicles simulated are slightly overestimated in France and the Netherlands,
- the shares of new registrations of alternative vehicles simulated are null in Sweden and UK despite the implementation of a rebate when the share of new registration is null at the base year.

This comparison leads to the conclusion that some revisions of the elasticity parameters for alternative vehicles are needed.

Table 39: Simulated shares of new registrations in the Netherlands

Segment	Registration tax	Shares new registrations 2012	Shares new registrations 2013	
	2013		Reference	Simulated
Battery electric	-5500.0	0.2%	0.6%	2.2%
Hybrid Plug-in electric	-5500.0	0.3%	4.8%	3.2%
Hybrid electric	0.0	0.5%	0.7%	0.9%
ICE <4 lge/100km	0.0	16.2%	17.0%	24.8%
ICE 4-5 lge/100km	1855.5	41.0%	45.7%	44.0%
ICE 5-6 lge/100km	5383.3	24.8%	19.1%	18.3%
ICE 6-7 lge/100km	8704.5	10.1%	8.0%	5.0%
ICE >7 lge/100km	14536.8	6.9%	4.1%	4.3%

Table 40: Simulated shares of new registrations in France

Segment	Registration tax	Shares new registrations 2012	Shares new registrations 2013	
	2013		Reference	Simulated
Battery electric	-7000.0	0.3%	0.5%	0.7%
Hybrid Plug-in electric	-4000.0	0.0%	0.1%	0.1%
Hybrid electric	-4000.0	1.4%	2.4%	3.4%
ICE <4 lge/100km	-550.0	4.1%	13.7%	4.3%
ICE 4-5 lge/100km	0.0	43.2%	48.1%	43.4%
ICE 5-6 lge/100km	0.0	35.1%	27.5%	37.0%
ICE 6-7 lge/100km	1250.0	10.2%	5.8%	7.7%
ICE >7 lge/100km	5000.0	5.7%	2.1%	3.5%

Table 41: Simulated shares of new registrations in Sweden

Segment	Registration tax	Circulation tax	Shares new registrations 2011	Shares new registrations 2014	
	2014	2014		Reference	Simulated
Battery electric	-4800.0	31.0	0.1%	0.4%	0.7%
Hybrid Plug-in electric	-4800.0	31.0	0.0%	1.1%	0.0%
Hybrid electric	0.0	31.0	0.0%	0.1%	0.0%
ICE <4 lge/100km	0.0	53.7	3.1%	6.9%	4.8%
ICE 4-5 lge/100km	0.0	65.8	27.0%	33.3%	30.2%

ICE 5-6 lge/100km	0.0	123.9	25.0%	24.4%	25.5%
ICE 6-7 lge/100km	0.0	200.6	28.2%	21.8%	24.5%
ICE >7 lge/100km	0.0	315.9	16.7%	12.0%	14.3%

Table 42: Simulated shares of new registrations in UK

Segment	Registration tax	Circulation tax	Shares new registrations 2010	Shares new registrations 2014	
	2014	2014		Reference	Simulated
Battery electric	-7499.0	0.00	0.0%	0.3%	0.0%
Hybrid Plug-in electric	-7499.0	0.00	0.0%	0.3%	0.0%
Hybrid electric	-15.0	15.00	1.1%	1.3%	1.2%
ICE <4 lge/100km	0.0	0.00	2.3%	4.6%	2.4%
ICE 4-5 lge/100km	-30.0	30.00	33.6%	42.7%	34.7%
ICE 5-6 lge/100km	-7.5	194.97	28.7%	31.2%	28.6%
ICE 6-7 lge/100km	-7.5	269.96	19.6%	12.9%	19.1%
ICE >7 lge/100km	502.4	427.44	14.6%	6.7%	14.0%

Wrap up: results of the validation

Translating the features of the policy schemes reported by the study into input for FEPIT necessarily implies some simplifications and interpretations. Therefore the results of the tool should be regarded as approximations of the reference results provided in the study. An exact match between the literature and the modelling results cannot be expected. Nevertheless, the large majority of the comparisons reported above suggest that the draft elasticities estimated for FEPIT are too large.

There is an explanation for this result: in the revised version of FEPIT the elasticities rule the share of registrations lost or gained by each segment, but in order to get a new set of registration shares adding to 1, all shares lost and gained are redistributed across segments. This reallocation process brings about an amplification of the effect of the elasticities. Initial elasticity values should be reduced in order to allow the tool estimate final results more in line with those reported in the studies used for its validation.

Furthermore, a revision of the approach used to estimate the impacts on new registrations of alternative vehicles is needed, especially to avoid that null values at the base year prevent the increase of their share in the projection year.

Proposed revised values of the elasticities

The results of the validation reported above suggest revising the parameters to reduce the elasticity of the model, due to the additional impact resulting from the reallocation process of the variation within each segment. Elasticities have been smoothed in order to minimize gaps between the simulation of the case studies with FEPIT and the results reported in the related documentations. A new set of elasticities resulting is proposed in the next tables, building on this result.

It should be noted that the differences between the literature values and the results obtained with the draft elasticities are not always of the same size. There is no single correction factor applicable to the draft elasticity values to get simulation results in line with the observations. The values proposed are the result of targeted adjustments of the draft parameters in order to find a better fit between model results and observed values. The performance of the tool with the new proposed elasticities, in comparison to the draft ones is presented in section 0.

CO2 based registration tax/feebate scheme

Both the parameters related to registrations by segment and fuel consumption by segment have been downsized. In addition, the impact for larger vehicles and alternative electric vehicles has been reduced.

Furthermore, the revisions included in the following tables also take into account that results are improved when the size of parameters for rebate and fee differentiating (as suggested also by Rivers and Schaufele, 2014).

Finally, a backup calculation has been added to avoid that null values at the base year prevent the increase of the share of alternative electric vehicles in the projection year. The approach takes into account the value of the rebate of the alternative vehicles (where implemented), the average taxation level of the conventional cars (weighted on composition mix at the base year) and an exogenous slightly increasing trend from 2012 onward (see Table 52).

Table 43: CO_2 based vehicle registration tax/feebate elasticities of registrations by segment

Segment	Draft elasticity[(a)]	Final elasticity[(a)]
Alternative electric vehicles	-0.70	-0.32 (rebate) -0.37 (fee)
Conventionally fuelled vehicles	-0.70	-0.42 (rebate) -0.49 (fee)
Higher fuel consumption segment	-0.35	-0.14 (rebate) -0.16 (fee)

(a) change of the natural logarithm of the registrations of cars in a given segment when a 1000 $ tax/rebate is applied

Table 44: CO_2 based vehicle registration tax/feebate elasticities of fuel consumption by segment

Parameter[(a)]	Draft value	Final value
Fixed constant	0.2238	0.1343
Cost related term	-0.037	-0.022

(a) Parameters of the equation %FC = K + P * ln(AvT) where %FR is the percentage change of fuel consumption and AvT is the average value of the tax across the segments

Table 45: Parameter for adjusting elasticities according to the initial fuel price

Parameter[(a)]	Draft value	Final value
FA	1.6	1.6

(a) Parameter FA of the equation AdEl = BEl * [1+ FA * (FP / BFP - 1)] where AdEl is the adjusted elasticity, BEl is the base elasticity, FP is the initial fuel price and BFP is a reference fuel price

Table 46: Parameter for adjusting the impact on new registrations of alternative vehicles in case of null values at the base year

Segment	Tax Parameter TA[(a)]	Year Parameter YA[(a)]
Battery electric	0.000053	0.000071
Hybrid Plug-in electric	0.000055	0.000071
Hybrid electric	0.000111	0.000147

(a) Parameters TA and YA of the equation [A1] (see Annex) applied to alternative vehicles to estimate the provisional minimum share at projection year

CO2 based circulation tax/feebate scheme

The results of the validation reported above also suggest revising the elasticity parameters related to circulation tax. This would reduce the additional impact resulting from the reallocation process of the variation within each segment.

Table 47: CO_2 based vehicle circulation tax/feebate elasticities of registrations by segment

Segment	Draft elasticity[a]	Final elasticity[a]
All	-0.14	-0.084 (rebate) -0.098 (fee)
Higher fuel consumption segment	-0.07	-0.042(rebate) -0.049 (fee)

(a) change of the natural logarithm of the registrations of cars in a given segment when a 1000 $ lifetime tax/rebate is applied

Table 48: CO_2 based vehicle circulation tax/feebate elasticities of fuel consumption by segment

Parameter[a]	Draft value	Final value
Fixed constant	0.0448	0.0269
Cost related term	-0.0074	-0.0044

(a) Parameters of the equation %FC = K + P * ln(AvT) where %FR is the percentage change of fuel consumption and AvT is the average value of the tax across the segments

Table 49: Parameter for adjusting elasticities according to the initial fuel price

Parameter[a]	Draft value	Final value
FA	1.6	1.6

(a) Parameter FA of the equation AdEl = BEl * [1+ FA * (FP / BFP - 1)] where AdEl is the adjusted elasticity, BEl is the base elasticity, FP is the initial fuel price and BFP is a reference fuel price

Fuel taxation

The results of the validation reported above suggest also revising the elasticity parameters for fuel taxes.

Table 50: Fuel taxation elasticities of registrations by segment

Segment	Draft elasticity[a]	Final elasticity[a]
All	-0.1	-0.08
Higher fuel consumption segment	-0.1	-0.04

(a) change of the natural logarithm of the registrations of cars in a given segment when a 1000 $ lifetime fuel tax is applied

Table 51: Fuel taxation elasticities of fuel consumption by segment

Parameter[a]	Draft value	Final value
Fixed constant	0.0320	0.0256

Cost related term	-0.0053	-0.0042

(a) Parameters of the equation %FC = K + P * ln(AvT) where %FR is the percentage change of fuel consumption and AvT is the average value of the tax across the segments

Table 52: Parameter for adjusting elasticities according to the initial fuel price

Parameter[(a)]	Draft value	Final value
FA	-2.5	-1.0

(a) Parameter FA of the equation AdEl = BEl * [1+ FA * (FP / BFP - 1)] where AdEl is the adjusted elasticity, BEl is the base elasticity, FP is the initial fuel price and BFP is a reference fuel price

Performance of the tool with the new elasticities

Table 53 below summarises the results of the application of FEPIT in comparison to the literature studies before and after the revision of the elasticities. The new elasticities perform significantly better than the draft ones and in most of the cases the results of the tool compare well with the reference data. As reference data are the result of an estimation process and of several assumptions, this result should be considered more as an indication of the magnitude than an exact measure of the policy impact. Taken this aspect into account, the differences between reference data and simulated results are generally within a reasonable range, with only a few cases where the tool significantly overestimates the effect of the policy.

Table 53: Performance of the tool with the new elasticities

Study, country and policy	Reference data	Performance with draft elasticity	Performance with final elasticity
Klier et al. (2012), France, Registration tax	• -7.95 g CO_2/km (-5.3%)	• -12 g CO_2/km (-8.2%)	• -6.9 g CO_2/km (-4.7%)
Klier et al. (2012), Germany, Circulation tax	• -1.67 g CO_2/km (-1.1%)	• -2.5 g CO_2/km (-1.6%)	• -1.5 g CO_2/km (-1.0%)
Adamou et al. (2011), Germany, Registration tax	• 75 Euro/t CO_2 -3.5% average fuel consumption • 150 Euro/t CO_2 -6.5% average fuel consumption • 225 Euro/t CO_2 -9% average fuel consumption • 300 Euro/t CO_2 -11.4% average fuel consumption	• 75 Euro/t CO_2 -7.0% average fuel consumption • 150 Euro/t CO_2 -13.3% average fuel consumption • 225 Euro/t CO_2 -17.6% average fuel consumption • 300 Euro/t CO_2 -21.2% average fuel consumption	• -75 Euro/t CO_2 -4.6% average fuel consumption • 150 Euro/t CO_2 -9.1% average fuel consumption • 225 Euro/t CO_2 -12.3% average fuel consumption • 300 Euro/t CO_2 -14.9% average fuel consumption
Kok (2011), the Netherlands, Registration tax	• -10 g/km from 2010 to 2011 (-7.4% from 2010)	• -16 g/km from 2010 to 2011 (-11.8% from 2010)	• -13.5 g/km from 2010 to 2011 (-10% from 2010)
Mueller et al. (2009), Switzerland, Registration tax	• -4% average fuel consumption new cars <160 g/km increased by 10%, • new cars > 200 g/km	• -20% average fuel consumption new cars <160 g/km increased by about 24%,	• -11.3% average fuel consumption new cars <160 g/km increased by about 19%,

Study, country and policy	Reference data	Performance with draft elasticity	Performance with final elasticity
	decreased by 5%	• new cars > 200 g/km decreased by 26%	• new cars > 200 g/km decreased by 15.6%
Ciccone (2014), Norway, Registration tax	• -6 to -8 gCO_2/km (-4% to -5%) • New cars >180 g CO_2/Km decreased by 12% points	• -28 g CO_2/km (-17%) • New cars >180 g CO_2/Km decreased by 35% points	• -22 gCO_2/km (-13.7%) • New cars >180 g CO_2/Km decreased by 35% points
Huse et al. (2014), Sweden, Registration tax (rebate)	• GCR symmetric scheme • New conventional cars <120 g CO_2/Km increased by 5.6% points, • FFVs <220 g CO_2/Km increased by 1.6%	• GCR symmetric scheme • New conventional cars <120 g CO_2/Km increased by 16.5% points, • FFVs <220 g CO_2/Km increased by 0.1%	• GCR symmetric scheme • New conventional cars <120 g CO_2/Km increased by 7.4% points, • FFVs <220 g CO_2/Km increased by 0%
Bunch et al. (2011), United States, Registration tax (also with fuel tax)	• $20/g/mi rate -4.8% average fuel consumption • $30/g/mi rate -7.2% average fuel consumption • $20/g/mi rate, high fuel price -5.2% average fuel consumption • $20/g/mi rate, low fuel price -3.6% average fuel consumption	• $20/g/mi rate -7.5% average fuel consumption • $30/g/mi rate -10.3% average fuel consumption • $20/g/mi rate, high fuel price -26.6% average fuel consumption • $20/g/mi rate, low fuel price -3.0% average fuel consumption	• $20/g/mi rate -4.5% average fuel consumption • $30/g/mi rate -6.3% average fuel consumption • $20/g/mi rate, high fuel price -14.3% average fuel consumption • $20/g/mi rate, low fuel price -3.7% average fuel consumption
EEA database, Greece, Circulation tax	• average fuel consumption from 6.22 lge/100 km to 5.72 lge/100 km (-8%)	• average fuel consumption from 6.22 lge/100 km to 5.62 lge/100 km (-9.5%)	• average fuel consumption from 6.22 lge/100 km to 5.72 lge/100 km (-8%)
Hennessy et al. (2010), Ireland, Registration tax and Circulation tax	• -11% average fuel consumption (-19 g CO_2/km) • new cars <140 g/km increased by 37%, • new cars from 140 to 155 g/km decreased by 2%, • new cars > 155 g/km decreased by 36%	• -15.4% average fuel consumption (-25 g CO_2/km) • new cars <140 g/km increased by 42%, • new cars from 140 to 155 g/km increased by 5%, • new cars > 155 g/km decreased by 47%	• -11% average fuel consumption (-18 g CO_2/km) • new cars <140 g/km increased by 23%, • new cars from 140 to 155 g/km increased by 6%, • new cars > 155 g/km decreased by 29%
Murray (2011), United Kingdom, Registration tax, Circulation tax and fuel tax	• -3% average fuel consumption (-4.5 g CO_2/km) • cars <125 g CO_2/km increased by 7%	• -3.7% average fuel consumption (-5.4 g CO_2/km) • cars <125 g CO_2/km increased by 10%	• -2.6% average fuel consumption (-3.9 g CO_2/km) • cars <125 g CO_2/km increased by 7%
Ryan et al. (2009), EU15,	• -1.8% average fuel consumption (-2.8 g CO_2/km)	• -3.2% average fuel consumption (-5.1 g CO_2/km)	• -2.2% average fuel consumption (-3.4 g CO_2/km)

Study, country and policy	Reference data	Performance with draft elasticity	Performance with final elasticity
Fuel tax			
Busse et al. (2013), United States, Fuel tax	• new cars <9.3 lge/100km increased by 5%, • new cars > 12.5 lge/100km decreased by 5%	• new cars <9.3 lge/100km increased by 18.5%, • new cars > 12.5 lge/100km decreased by 13.7%	• new cars <9.3 lge/100km increased by 11%, • new cars > 12.5 lge/100km decreased by 5%
Mock, P. and Yang, Z. (2014), The Netherlands, France, Sweden, United Kingdom, Incentives to electric vehicles	The Netherlands • Battery electric 0.6% • Hybrid Plug-in electric 4.8% • Hybrid electric 0.7% France, • Battery electric 0.5% • Hybrid Plug-in electric 0.1% • Hybrid electric 2.4% Sweden • Battery electric 0.4% • Hybrid Plug-in electric 1.1% • Hybrid electric 0.1% United kingdom • Battery electric 0.3% • Hybrid Plug-in electric 0.3% • Hybrid electric 1.3%	The Netherlands • Battery electric 2.2% • Hybrid Plug-in electric 3.2% • Hybrid electric 0.9% France, • Battery electric 0.7% • Hybrid Plug-in electric 0.1% • Hybrid electric 3.4% Sweden • Battery electric 0.7% • Hybrid Plug-in electric 0.0% • Hybrid electric 0.0% United kingdom • Battery electric 0.0% • Hybrid Plug-in electric 0.0% • Hybrid electric 1.2	The Netherlands • Battery electric 1.3% • Hybrid Plug-in electric 1.9% • Hybrid electric 0.9% France, • Battery electric 0.6% • Hybrid Plug-in electric 0.1% • Hybrid electric 2.7% Sweden • Battery electric 0.5% • Hybrid Plug-in electric 0.7% • Hybrid electric 0.003% United kingdom • Battery electric 0.7% • Hybrid Plug-in electric 0.7% • Hybrid electric 1.2

Source: TRT estimation

Annex

This section reports information on the approach implemented in FEPIT to estimate the impacts on new registrations of alternative vehicles (Battery electric, Hybrid Plug-in electric, Hybrid electric). A specific structure has been defined in order to avoid that null values at the base year prevent the increase of their share in the projection year.

More in details, a minimum share has been introduced as provisional value at the projection year, in order to simulate also the increasing trend of alternative vehicles registrations observed in the recent years. This approach estimates a minimum share of new registrations taking into account the value of the rebate of the alternative vehicles (where implemented), the average taxation level of the conventional cars (weighted on composition mix at the base year) and an exogenous slightly increasing trend from 2012 onward. Namely, the following equation applies:

$$MinSh_e = TA_e * [- Rb_e + \sum_s (T_s(t0)* Sh_s(t0)) - \sum_s (T_s(t)* Sh_s(t))]/1000 + YA_e * max(0, t - 2012)$$ [Eq. A1]

where Rb_e is the rebate for alternative vehicle segment *e*,

T_s is the tax/rebate for other segments *s* at the base year t0 and projection year t,

Sh_s is the share of other segments *s* at the base year t0 and projection year t.

The parameters of the equation are reported in the table below (the same values as Table 52). These parameters have been calibrated on the basis of the analysis and comparison with recent trends of uptake electric vehicles in some European countries, as reported in paragraph 0.

Table A: Parameter for adjusting the impact on new registrations of alternative vehicles in case of null values at the base year

Segment	Tax Parameter TA[(a)]	Year Parameter YA[(a)]
Battery electric	0.000053	0.000071
Hybrid Plug-in electric	0.000055	0.000071
Hybrid electric	0.000111	0.000147

(a) Parameters TA and YA of the equation [A1] applied to alternative vehicles to estimate the provisional minimum share

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9, rue de la Fédération, 75739 Paris cedex 15
Layout in France by IEA, December 2015