User Guide
Feebate Simulation Tool

Authors:
Arno Schroten (CE Delft)
Sanne Aarnink (CE Delft)
Ben Gardiner (Cambridge Econometrics)
Wojtek Szewczyk (Cambridge Econometrics)
Shalini Mittal (Cambridge Econometrics)

ce cambridge econometrics

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Contents

1 Introduction

1.1 Background

Transport accounts for about a quarter of energy-related global CO_2 emissions, a share that is likely to be higher in the future unless strong mitigating action is taken (IEA, 2009). Considering that passenger cars have caused about half of global transport emissions, most developed countries are actively implementing policies to reduce emissions from passenger cars.

While policies to improve the vehicle's fuel economy (i.e. reduce the liters consumed by the vehicle per kilometer) and more generally to reduce the CO_2 emissions from the vehicle are common in developed countries, most developing and transition countries have not (yet) implemented such policies. Consequently, significant gains can still be obtained in these countries. Given the expected high share of developing and transition countries in future transport-related CO_2 emissions (ICCT, 2012), it is important to stimulate the uptake of emission and fuel economy policies in these countries.

Feebate systems are one of the policy options available that developing and transition countries can implement to reduce passenger car emissions. Feebate systems impose a fee on vehicles with high CO_2 emissions per kilometer or a low fuel economy (i.e. high fuel consumption) and provide a rebate to vehicles with low CO_2 emissions per kilometer or a high fuel economy (i.e. low fuel consumption). Feebate systems can provide an interesting policy option for developing and transition countries, for two main reasons.

Firstly, feebate systems can be designed as an instrument that does not impact the governmental budget (i.e. it can be a budget-neutral instrument), which is likely to be an attractive feature for governments from developing and transition countries with limited budgets (Greene et al., 2005).
Also, this enables governments to implement this instrument for a longer period of time as compared to some other policy instruments that reduce governmental budgets (e.g. subsidies for example). Although this argument also applies to taxes, feebates may be perceived more positively by consumers and manufacturers than taxes.

Secondly, feebates may be more appropriate for developing and transition countries compared to other instruments, especially compared to those targeting manufacturers, such as CO_2 standards. In contrast to developed countries, transition and developing countries import most of their vehicles rather than producing vehicles themselves. Feebate systems could be used to affect the fuel-efficiency of these imported cars, both new and used (second-hand).

For both reasons, feebate systems may be an appropriate instrument for governments from developing and transition countries. To assist policy makers from these governments, the International Council on Clean Transportation (ICCT) and the Global Fuel Economy Initiative (GFEI) asked CE Delft and Cambridge Econometrics to develop an easy to use tool that supports them in exploring and designing a feebate system with a modest amount of input data.

1.2 Quick introduction to feebate systems

As mentioned above, feebate systems impose a fee on vehicles with a low fuel economy/high CO_2 emissions per km and provide a rebate to vehicles with a high fuel economy/low CO_2 emissions per km. A pivot point determines which vehicles are eligible for a fee or rebate and can be set at a particular CO_2 emission level (e.g. gCO_2/km), fuel economy level (e.g. l/100 km), or other measurement metric. In Figure 1, this basic principle of a feebate system is shown graphically.

Figure 1   Basic principle of a feebate system design (for two different rebate function shapes)
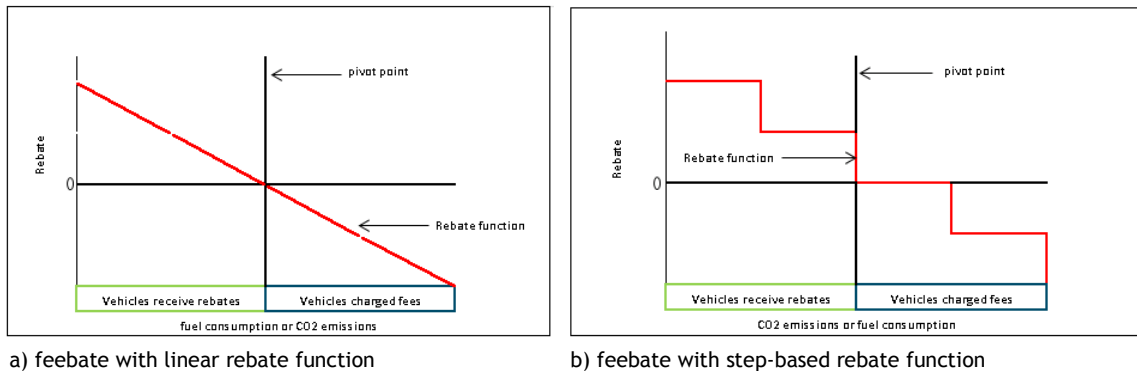
a) feebate with linear rebate function   b) feebate with step-based rebate function

Source: ICCT, 2010, adjusted by CE Delft.

The pivot point does not (directly) influence the efficiency improvements that will be realised with the feebate, as this is mainly determined by the slope of the rebate function (i.e. the slope of the red lines in Figure 1). The steeper the slope (also referred to as the 'rate') the stronger the incentive that is given to manufacturers to improve the performance of a vehicle and/or to consumers to purchase more efficient vehicles, as it will pay-off relatively more to improve a vehicle (Greene et al., 2005; Peters et al., 2008).
The shape of the rebate function also influences the efficiency improvements that will be obtained with the system. As can be seen in Figure 1, there are different possible design options. These include linear functions (a), step-based functions (b), and combinations hereof. A linear function will be more effective, as it provides an incentive to improve every vehicle, while a step-based function mostly provides an incentive to improve vehicles that are close to a given step.

A feebate system can be a budget-neutral governmental policy. If the pivot point is set appropriately, it will balance the fees the government receives and the rebates it pays. Note that it is also possible to set a pivot point that results in net revenues to the government (i.e. more fees than rebates). As the fuel-efficiency of the fleet improves over time, the pivot point also has to be adjusted regularly, which can be once a year or once every few years for example. If the pivot point is never adjusted, the total amount of rebates will increase and the amount of fees will decrease.

> *More detailed background information on feebate systems and their (dis)advantages can be found in Annex A. Annex B provides examples of implemented feebate(-like) systems worldwide.*

1.3 Objectives

As shown in the previous section, feebate systems can be designed in a variety of ways. The design choices made will influence both the vehicle impacts (i.e. efficiency improvements obtained) and financial impacts (i.e. the revenues and expenses to the government) of the feebate system. Therefore, this feebate simulation tool aims to provide users insight into the various possibilities for designing a feebate system for a particular country and the vehicle and financial impacts that can be expected for this country with the design choices made. This, in turn, can assist users of the tool in national-level policy discussions and actual feebate design.

More specifically, the tool should be:
− simple-to-use;
− robust;
− informative and;
− able to design a feebate scheme for a particular country with a modest amount of input data.

The scope of this feebate simulation tool is limited to passenger vehicles (both new and second-hand) and to CO_2 emissions only. Therefore, vans, heavy duty vehicles and all other emissions are not included. The user does not need any data to use the tool, as several default countries have been included in the tool. However, ideally, the user would insert vehicle registration data for his/her country to make the results better fit the situation in the country for which policy is being discussed. Data inserted into the tool should follow the format of the data already existing in the tool as defaults in order to ensure proper function of the tool. Directions on data collection and upload are included in Chapter 2.

1.4 Tool and user guide

In addition to a simple-to-use yet robust tool to stimulate feebate systems with, a user guide has been developed, providing instructions on how to use the tool. Additionally, background information on feebate schemes, design options, and the pros and cons of different designs have been included in annexes of the user guide.

The user guide lies in front of you, and as shown in Figure 2 and Table 1, the remaining chapters of this user guide each represent and explain a tab/step of the tool.

Figure 2   **Navigating through the tool by using the tabs**

Table 1   **General overview of the tool and of additional information**

Tab name	Functionalities	Instruction for using tool:	Additional background information:
Start Here	Short explanation of feebate systems and introduction to the tool	Chapter 0	Annex A Annex B
Input Data	Contains the data for the default countries. In this tab the user can also insert his own data.	Chapter 2	
Feebate Design	Design of the actual feebate system	Chapter 3	Annex C
Results	Shows the impact of the feebate system you have designed	Chapter 4	

In addition to this user guide, assistance is available within the tool itself by clicking on the question marks (?).

2 Data input for the tool

> **Tab:** Input Data (vehicle data) and Feebate Design – Advanced design options – Budget control (exchange rate)
>
> **Action: Collecting the necessary data** (Section 2.1) **and inserting your** data in the tool (Section 2.2)

2.1   Data collection

Even if you have no data available for your country, you can still design a feebate system using default (or pre-set) data which has been included in the tool for a number of countries (see Input Data tab). If you want to use this default data to get a sense of how the tool works, you can skip this step and go directly to the next step in Section 3.1.

However, ideally, the user inserts country-specific data of a) newly-registered vehicles (this can include both new and used vehicles) and their characteristics (including price) and of b) the currency exchange rate. This will lead to results that are customised to a given country's situation, and therefore more relevant for decision-making. Both aspects are further described below.

2.1.1   New vehicle registrations

The main input for the feebate simulation tool is a record of newly-registered vehicles in your country. A newly-registered vehicle can be a new (i.e. newly manufactured) or a used (i.e. second-hand) car that is sold in a particular registration year. The GFEI has developed a baseline methodology that can help countries with gathering the necessary data for a baseline and can also be used in the tool. This methodology provides useful information on the format of the record, which information can be included in the record, where this data can be found, and provides examples of countries that have already set up a record.

> *More information on the GFEI baseline methodology can be found at:*
> *http://www.unep.org/transport/gfei/autotool/nextsteps/developing_a_baseline.asp*

An example of a new vehicle registration record is shown in Table 2. Note that there are many different aspects that can be included and formats that can be used for generating your vehicle registration record; this depends on your own needs and the purposes your registration record needs to fulfil. The aspects shown in Table 2 are compatible with the use of this particular tool.

Table 2   Example of a new vehicle registration record

Reg. Year	Make	Model	Model year	Body Type	Condition	Segment	Fuel type	Price	gCO$_2$/km	Power	Weight	L/100 km	Size
2005	BMW	316I	1989	S. WAGON	Used	a	b	c	176	d	e	7,5	f
2005	CHEV	NULL	2005	SALOON	New	a	b	c	145	d	e	6.2	f

a   The segment can be A, B, C, D, E, F, SUV, which is further explained in the GFEI methodology (link above).

b   In the tool, fuel type can be categorised with the main fuel types (petrol, diesel, gas/LPG), but you can also include hybrid/petrol, hybrid/diesel, electric, flexible, natural gas, ethanol-petrol mix, fuel cell or unspecified if you have this data available.

c   Price can be registered in USD or in your own currency. Both are compatible for the tool.

d   There are different units for power: you can generate the registration record with the unit used in your country (e.g. in horsepower of the car (HP)). You can insert any unit in the tool though, as long as all data for this variable is reported in this unit.

e   There are different units for weight: you can generate the registration record with the unit used in your country (e.g. in kilogram (kg)). You can insert any unit in the tool though, as long as all data for this variable is reported in this unit).

f   There are different units for size: you can generate the registration record with the unit used in your country (e.g. in inches). You can insert any unit in the tool though, as long as all data for this variable is reported in this unit.

Not all aspects shown in Table 2 are necessary to use the feebate simulation tool. However, in order to generate reliable results with the tool for your specific country, you are strongly advised to at least collect the following data:
− Price of the vehicle in USD or local currency.
− Emissions in gCO$_2$/km and/or fuel economy (l/100 km).
− The quantity of vehicles registered for each model (to assist data aggregation). Table 2 concerns a micro-dataset, which means that all registered vehicles are included separately (i.e. quantities of all rows are 1). It is also possible to insert an aggregated dataset in the tool, in this case one row can contain multiple vehicle registrations and models (i.e. categorised vehicle registrations). This is further explained in Section 2.2.

If you do not have data for one of these aspects you can leave these cells empty for now. The tool will not work properly in this case though and will provide assistance with generating a solution (explained in Section 2.2).

The data aspects shown above are most important when you operate the tool for your country. However, if you have collected data on the following aspects as well, some advanced design options will be enabled in the tool (e.g. attribute adjustments, further explained in Section C.6.):
− registration year;
− vehicle segment (A, B, C, D, E, F, SUV), which is further explained in the GFEI methodology (see the link above);
− fuel type (petrol, diesel, gas/LPG, but also natural gas, ethanol-petrol mix, hybrid/petrol, hybrid/diesel, electric, flexible, fuel cell and unspecified can be entered in the tool);
− vehicle weight in kilograms or comparable unit;
− power in HP or comparable unit;
− vehicle size in inches or comparable unit.

2.1.2 Exchange rate

You will have to insert an exchange rate between the currency used in the vehicle price data as the tool defaults to United States dollars (USD). If the currency of your dataset is in USD you will still have to enter an exchange rate of 1 in the tool (instructions can be found in Section 2.2).

If your dataset is in another currency, you will need to determine the exchange rate. There are many currency converters available, such as: http://www.oanda.com/currency/historical-rates/. In this currency converter, you can select 'historical exchange rates' for your currency, for the registration year of your data. By selecting 'table' the converter shows the average exchange rate of that year in local currency/USD: you can insert this value in the tool (instructions in Section 2.2).

Figure 3   **Example of a currency converter tool**
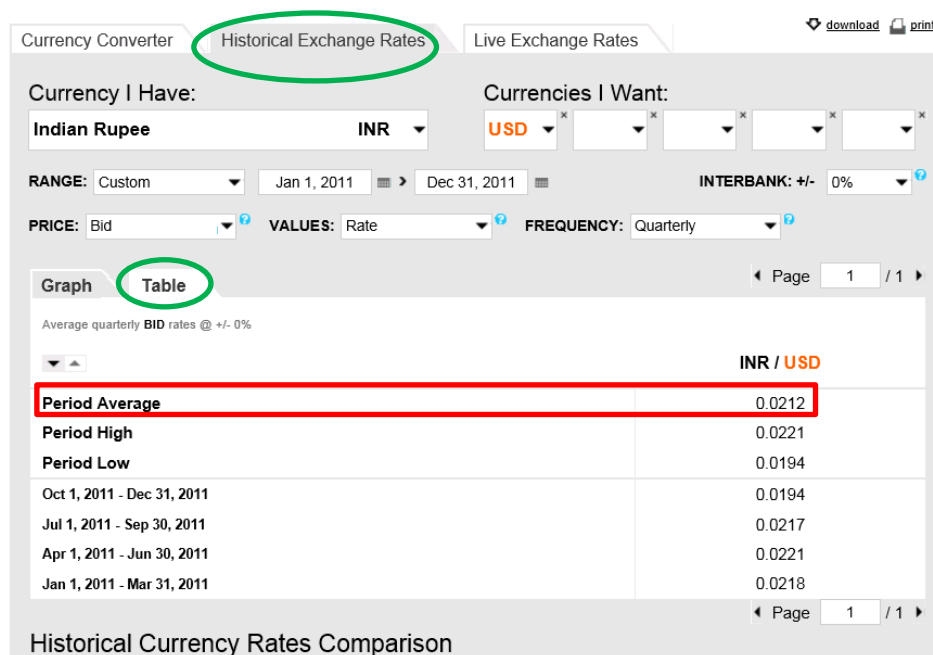
2.2 Entering the data in the tool

Once you have collected the data on newly-registered vehicles, this data can be inserted in the tool. However, in order to do so, you may need to reorganise your dataset.

Firstly, you have to decide whether you want to apply the feebate system to registered newly manufactured vehicles, newly-registered second-hand vehicles, or both. This has implications for the dataset you have to insert, which is further described in Box 1.

Box 1   Applying the feebate system to new and/or second-hand vehicles?

In the majority of cases, vehicle registration records contain both registered new and second-hand car purchases. However, you can choose to apply the feebate system to newly manufactured car sales only, to second-hand car sales only, or to all newly-registered vehicles (i.e. to both new and second-hand car sales). If you choose to only apply the feebate system to new or to second-hand vehicles, you need to eliminate all second-hand or all new vehicles from your record, respectively. I.e. the data you insert needs to only cover new vehicle or only second-hand vehicle sales.

If you want to apply the feebate system to all (i.e. both new and second-hand) newly-registered vehicles for a given year, you can insert a mixed total vehicle registration dataset. However, assumptions will need to be made about the car fuel economy rating of second-hand vehicles. This can either be done by assuming that the fuel economy of used vehicles is the same as a new vehicle of the same make and model, or by applying a 'discounting' rate to account for the fact that older vehicles of the same model generally have a relatively higher fuel consumption than new vehicles. This will have to be decided by the tool user, based on national circumstances.

Secondly, you need to decide whether you want to insert your data on individual vehicle level (i.e. a micro-dataset), as was shown in Table 2, or whether you want to insert an aggregated dataset as is shown in Figure 4. In the former case, each row contains data on one vehicle. In the latter case, each row has quantities larger than 1 (except when only one vehicle was registered for a category). In the example shown in Figure 4, the data has been aggregated for vehicle segments with a particular fuel type. Lower levels of aggregations are also possible. You can for example aggregate the same models. Whichever aggregation you choose, you need to ensure that you insert an average price, emission level, fuel consumption, etc., for each category, which you can determine with your micro-dataset. The advantage of an aggregated dataset is that the tool will run faster with this dataset compared to a micro-dataset. However, using an micro-dataset, on the other hand, provides more reliable results.

Finally, you must ensure that your micro or aggregated dataset has exactly the same format and sequence of columns as the tool (blue rectangle in Figure 4). I.e. column 1 is the registration year, column 2 is your country name, column 3 is the vehicle size segment (A, B, C, D, E, F, SUV), etc. You may therefore have to eliminate some columns or add some columns in your micro-data or aggregated dataset. Note that also in case of a micro-dataset you have to insert a column with quantity. The quantity of all rows is 1. If you do not have data available for a particular row, you can leave this column empty (except for the columns country, quantity, price and CO_2 or l/100 km, for these variables at least some values need to be inserted).

Figure 4 Screenshot of input data feebate tool

Year	Country	Segmen	Fuel	Quantity	Price	Emissions	Power	Weight	l/100km	Size
2011	Australia	A	Diesel	208,0	37875,0	122,0	110,0	1555,6	4,675	254,0
2011	Australia	A	Petrol	10249,0	35300,0	138,5	139,5	1367,5	5,404	144,0
2011	Australia	B	Diesel	2589,0	26190,0	132,5	109,0	1735,0	4,609	384,0
2011	Australia	B	Petrol	106770,0	26490,0	158,9	138,0	1587,5	6,382	275,0
2011	Australia	C	Diesel	16308,0	46930,2	143,5	154,5	1986,0	5,937	227,0
2011	Australia	C	Ethanol-Petrol M	73,0	57950,0	222,0	200,0	1587,5	9,300	262,5
2011	Australia	C	Hybrid/Petrol	2915,0	42990,0	98,0	93,5	1747,5	4,129	174,6
2011	Australia	C	Petrol	167632,0	57445,0	175,5	219,5	1876,0	7,585	134,5
2011	Australia	D	Diesel	15310,0	69945,0	172,5	200,5	2169,0	6,168	176,0
2011	Australia	D	Gas/LPG	3082,0	46312,5	217,0	240,5	2505,0	11,935	136,9
2011	Australia	D	Hybrid/Petrol	5206,0	38490,0	121,0	175,5	2110,0	5,200	183,7
2011	Australia	D	Petrol	140204,0	80995,0	216,5	276,5	2249,5	8,843	0,0
2011	Australia	E	Diesel	4045,0	135260,3	179,0	245,5	2525,0	6,766	190,0
2011	Australia	E	Hybrid/Petrol	30,0	188764,0	199,5	345,0	2542,5	8,167	165,4
2011	Australia	E	Petrol	60810,0	258699,5	254,0	384,0	2295,0	9,552	220,0
2011	Australia	F	Diesel	17,0	69061,7	144,0	170,0	1770,0	5,900	189,0
2011	Australia	F	Ethanol-Petrol M	19,0	405714,0	384,0	575,0	2750,0	16,500	256,0
2011	Australia	F	Petrol	6238,0	697132,5	275,0	370,5	2168,0	10,194	384,0
2011	Australia	SUV	Diesel	29120,0	45990,0	227,0	240,0	2510,0	7,935	288,5
2011	Australia	SUV	Petrol	122619,0	39500,0	262,5	321,5	2367,5	9,577	0,0
2011	Brazil	A	Ethanol-Petrol M	67632,0	33745,0	174,6	85,5	1257,5	6,703	
2011	Brazil	A	Petrol	22029,0	87465,0	134,5	129,5	1385,0	6,387	
2011	Brazil	B	Ethanol-Petrol M	1494129,0	48385,0	176,0	100,0	1511,5	7,224	
2011	Brazil	B	Petrol	35374,0	48765,0	136,9	108,0	1490,0	5,900	
2011	Brazil	C	Ethanol-Petrol M	527893,0	55645,0	183,7	109,5	1646,0	7,105	
2011	Brazil	C	Hybrid/Petrol	175,0	104181,0	0,0	158,0	#DEEL/0!	0,000	
2011	Brazil	C	Petrol	66023,0	161063,0	100,0	225,0	1990,0	7,548	

Buttons: *Choose country or upload new data* · *Back to Design*

Tabs: Start here | Input_Data | Feebate Design | Results | Blad1

Your dataset is now ready to be inserted In the tool. To do so, navigate to the tab 'Input Data' (red circle in Figure 4).

Inserting the dataset in the tool
Table 3 summarises the steps you need to follow to insert your data in the tool.

Table 3 Steps that need to be followed to insert data in the tool

Step	Action
1	Make sure your own dataset has the same format as the dataset shown in Figure 4 (i.e. same type of information and in the same ordered columns).
2	Select the cells that contain a value in your dataset and copy them (Ctrl + C).
3	Go to the feebate tool Excel sheet and select the input data tab (circled red).
4	Go to the first empty row of the input data tab (you will have to scroll down at least 200 rows) and select the first cell (i.e. cell in the first column) of the first empty row in the data sheet.
5	Paste your data in the feebate tool (Ctrl + V).
6	You now need to insert an exchange rate in the tool (also if your prices already are in USD!). To do so, you go to the Feebate Design tab and click on the button 'Advanced Design Options'. You will now be redirected to the advanced controls section where you click on the button 'budget control'. If your country and currency is listed here, you can go to step 7. If it is not, you can overwrite the values in one of the rows that states 'country/currency/rate' (see the blue rectangle in Figure 5) and overwrite these values with your own country name, currency, and exchange rate (see Section 2.1.2). Note that your country name should be spelled identically to the country name you have inserted in column 2 in the 'Input Data' tab. If your price data is in USD, enter an exchange rate of 1.
7	Go back to the 'Input Data' tab and press the button 'Choose country or upload new data' (green circle in Figure 4). In the pop-up which appears you press 'Refresh selection'. Your country can now be selected in the drop-down menu, which is further explained in Section 3.1.

Figure 5 Inserting an exchange rate

Missing data

If you insert a dataset with missing data (i.e. with empty cells), the reliability of the results may decrease and some advanced design functions may be disabled. If the latter is the case, the tool will notify you hereof when you try to select a design that has been disabled due to your dataset.

The tool will also provide you with a general warning when there are any missing or problematic data points when you select your country dataset (see Section 3.1 for the instructions). In this case, you get the warning shown in Figure 7, which shows how many data is missing or invalid (blue rectangle). 'Count' shows the number of problematic cells, whereas the '%' shows the share of rows with a problematic cell for the respective variable. The ideal way to proceed when you get this warning (especially when you use an aggregated dataset), is to explore if you can add data for the problematic data points. You can for example try to estimate the missing cells (which will have been coloured orange in the tool) with the data of other default countries in

the 'input data' tab or with data from comparable categories in your own dataset. To do so, you need to click on the red circled button 'Make no changes and return to the data' shown in Figure 6.

If you are unable or unwilling to estimate values for the problematic cells, you have three other options to deal with the missing data points:

− *Ignore* the problematic data points. In this case your dataset is uploaded in the tool *with* the problematic data points. This will disable some design options. If you have missing data for fuel economy (L/100 km) for example, you cannot select this as a metric when designing your feebate system.
− *Delete* the problematic data points. In this case, the rows with problematic data will not be uploaded. Be careful with choosing this option if you have too much missing data (%) for a variable, as you will reduce the size of your dataset significantly in this case. Especially with an aggregated dataset this may be problematic (as one row may contain a large number of vehicle registrations). Choosing to delete data will enable you to use all design options incorporated in the tool though.
− *Choose a (/another) default country*. You may also decide to choose a, or if you already used a default country to choose another default country that has less problematic data points.

A combination of ignore and delete is also possible, by choosing different options for different variables. Once you have selected which data points you whish to ignore and/or delete, you need to click on the green circled button 'Proceed with selection as above' in Figure 6. To choose another default country you need to click the red circled button and start over with the instructions for choosing a country outlined in Section 3.1.

Figure 6   Missing data warning in the tool

Data Overview

The section below provides overview of data for the selected country. It also provides options on how to proceed with problematic data points, in any.

Identifying problematic data points

The problematic data points constitute missing data, error data (i.e. #N/A, #VALUE!, #REF!, #DIV/0!, #NUM!, #NAME? and #NULL) or zero value. The zero value is considered problematic for only variables which should not take zero values (weight, size), but is acceptable for Emissions (usually equal to zero for electric vehicles).

The table below shows the number of problematic data points (Count) and percentage of the variable with cannot be used (%)

How to deal with problematic data points

There are four options to deal with the existence of problematic data points:

> Add/adjust the missing/problematic data; for this option, cancel this step and go back to the data and review/adjust it before uploading again.
> Ignore the problematic data points; in the table below it could be indicated for which variables you would like to ignore the problematic data points.
> Delete the problematic data points; in the table below it could be indicated for which variables you would like to delete the problematic data points (entire row of data containing the problematic data point will be deleted)
> Run the tool for (another) default country as an alternative; for this option, cancel this step and choose to use the data for another country.

Any deletion is only temporary, and the original data is kept intact. You can always restore the original data by re-loading the country again.

Warning! Deleting significant part of data can affect representability of the dataset and, if used for simulation, can produce biased results!

Variable	Count	%	Ignore	Delete
Segment	0	0	⦿	○
Fuel	0	0	⦿	○
Quantity	0	0	⦿	○
Price	0	0	⦿	○
Emissions	0	0	⦿	○
Power	0	0	⦿	○
Weight	6	15	⦿	○
l/100km	4	10	⦿	○
Size	39	100	⦿	○

Proceed with the selection

Make no changes and return to the data

3 Design of the feebate system

> **Tab:** 'Feebate Design'
> **Actions:** In this tab you can design your feebate system
> **More information:** Annex C

You can now proceed with designing the feebate system for your (default) country by navigating to the tab 'Feebate Design' in the tool (red circle in Figure 7). In this tab, every green cell is adjustable by the user, while blue cells cannot be adjusted. For each design parameter you can choose from a number of options from drop-down menus (e.g. on pivot point control, the metric, etc.). The little question marks (**?**) provide explanatory information on the design options and the pros and cons of these options.

Figure 7   **Screenshot of feebate design in feebate tool**
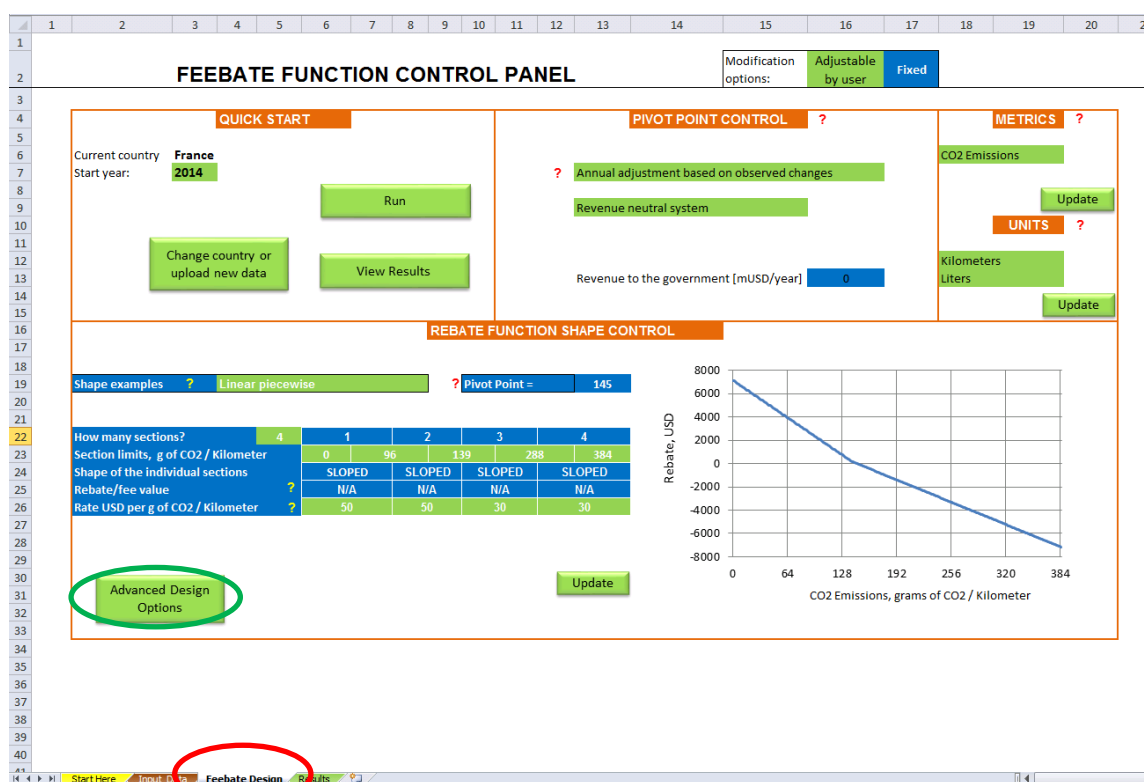
Each main design feature shown in the screenshot above (orange boxes) is further explained in the following sections.

3.1 Quick start: Choosing a (default) country

In the quick start panel that is positioned in the upper left corner of the 'Feebate Design' tab, you can choose the country that you want to apply the feebate system to by clicking on the 'Change country or upload new data' button (red circle in Figure 8).

Figure 8   Selecting a (default) country and starting year in the quick start panel

When you click on this button, you are redirected to the 'Input data' tab where a pop-up screen - as shown in Figure 9 - appears. From the drop-down menu in this pop-up screen (green circle), you can choose a country from a number of pre-set, or default, countries that are already programmed into the tool with their vehicle registration data. If you have not entered your own data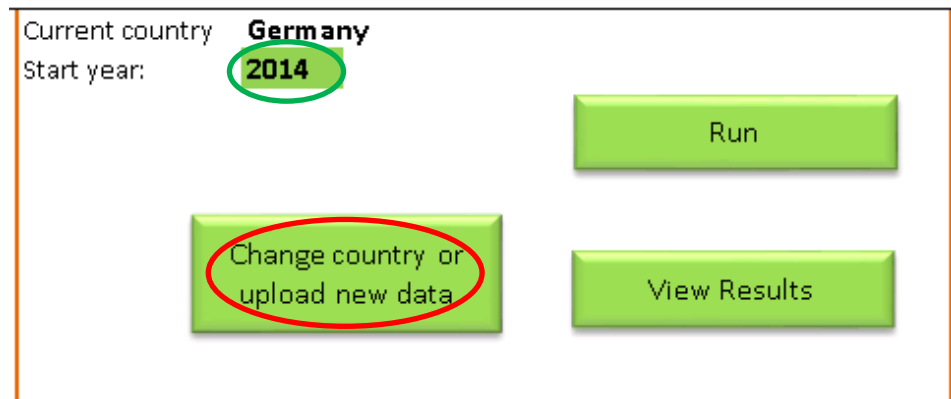, you can select a default country that best represents your own country's situation. If you have entered your own country data (as per the previous step), you can now select your country in the drop-down menu. After selecting your country of choice, you need to click on the button 'choose country', which redirects you back to the 'Feebate design' tab.

If your country does not appear in the drop-down menu while you have inserted your own vehicle registration data, you need to click on the button 'Refresh Selection'. If your country still not appears in the drop-down list, you may have forgotten to insert an exchange rate (see Section 2.2 for instructions). Yet another cause can be that the country name you have inserted for your exchange rate is not exactly the same as the country name you have inserted in the 'Input data' tab.

If you do have vehicle registration data available, but have not inserted this data in the tool yet, you need to click on the 'Upload new data' button first. Chapter 2 explains how you can insert your data.

Figure 9   Selecting a country for the feebate system
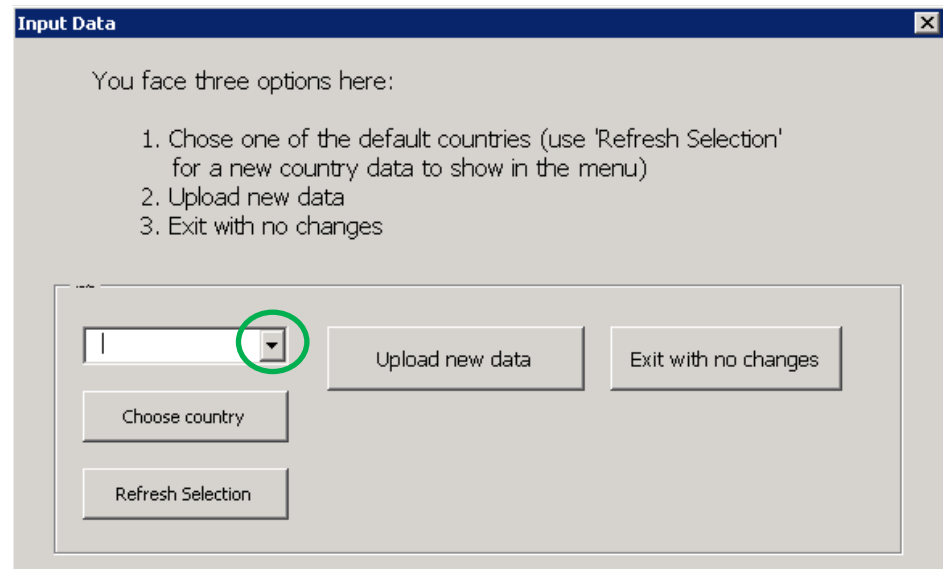
Next to choosing a country, you can also choose the starting year for your assessment by overwriting the default value of 2014 (green circle in Figure 8). We recommend to choose the current year here.

After choosing a country and staring year, you can start generating results with the default feebate system shown in this tab by clicking on the 'Run' button shown in Figure 8.

You can also continue with the actual design of your own feebate system, by following the steps in the next sub-sections. You should click the 'Run' button every time you change any design element of your feebate system to ensure updated results. You can view results by clicking on the 'View Results' button.

3.2   Pivot point control

The pivot point divides vehicles charged fees from those receiving rebates. The user has to make two main design choices with respect to the pivot point control:
−   The method for adjusting the pivot point: by adjusting the pivot point yearly or once every few years, the pivot point is adjusted for improvements of the fleet's efficiency over time. Your options are:
  •   annual adjustment based on observed changes;
  •   annual adjustment based on fixed criteria;
  •   manual pivot point control;
  •   lagged adjustment based on trigger.
−   The pivot point itself: whether the pivot point needs to generate a
  •   revenue neutral system (i.e. fees and rebates are in balance);
  •   net revenue to the government (i.e. more fees than rebates).
The default value is annual adjustment based on observed criteria with a revenue neutral pivot point, as this option has the lowest risk of any shortfalls in later years.

More detailed background information on the pivot point and on the annual adjustment of the pivot point and the pros and cons of the options can be found in Annex C.5 and in Annex C.8, respectively.

The user first has to choose for one of the four pivot point adjustment methods (green circle in Figure 10). Each of these four options requires different inputs (as evidenced in Figure 10 to Figure 12) and is described in more detail below.

For both annual adjustment methods (shown in Figure 10), the user can choose from a drop-down menu for a revenue neutral system or net revenue to the government (red arrow). If you choose this latter option, you can also specify the amount of yearly revenue you want to generate by overwriting the default value of 20 million USD (blue circle). As the model calculates the required pivot point (for generating the governmental balance chosen), you cannot change the pivot point manually in the 'rebate function shape control' (blue circle in Figure 15). When you have chosen 'Annual adjustment based on observed changes', the tool calculates the pivot point for the remainder of the period as well with the actual efficiency improvements generated. When you have chosen fixed criteria on the other hand, the model calculates the pivot point for the first year, but needs a criterion for shifting the pivot point in the years hereafter. You can provide this criterion by overwriting the default value (blue arrow). The pivot point will shift with this percentage irrespective of the actual shift in the vehicle fleet's efficiency. Hence, the governmental balance may increase or decrease in the years hereafter. The default value is a shift of 3% (i.e. it is expected that the fleet becomes 3% more efficient per period).

Figure 10   Choosing a pivot point and its adjustment: annual adjustment options

Option A: annual adjustment based on observed changes

Option B: annual adjustment based on fixed criteria

If you do want to determine your pivot point manually, you can select the option 'Manual pivot point control' (Figure 11). When you select this option, the pivot point shown in the Rebate function Shape Control will become green and therefore can be adjusted (blue circle in Figure 15). Note that with this option, you have no guarantees about the impact of your pivot point on the governmental balance and that the pivot point value is kept constant for the entire period.

Figure 11   Choosing a pivot point without adjustment: manual pivot point control
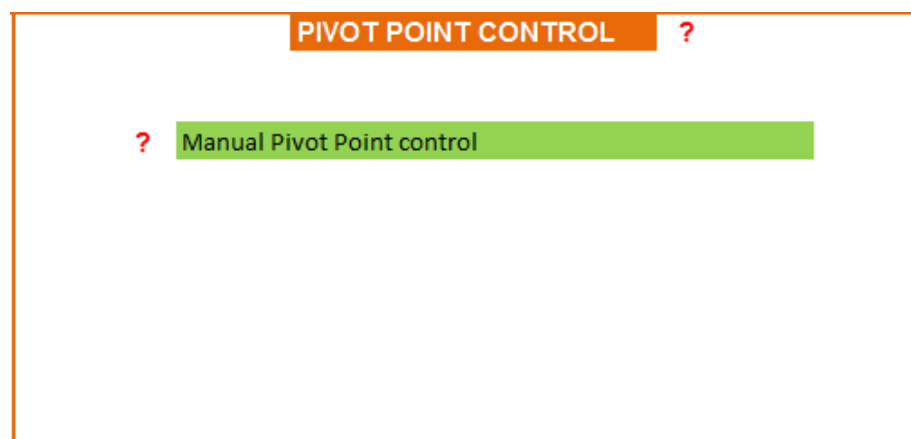
If you do not want to adjust your pivot point every year, you can choose the option 'Lagged adjustment based on trigger' (Figure 12). In this case, the pivot point will be shifted with a *fixed criteria* (black arrow), *n years* (red arrow) after a specified *trigger* (i.e. condition, blue arrow) has been met. More information on these parameters and the way to use them in the tool is given in Table 4.

Table 4   Parameters that can be adjusted for lagged adjustment based on trigger

Parameter	Meaning
Lead time	This parameter specifies the number of years after which the pivot point is adjusted once the trigger point is met. In the example shown in Figure 12 the pivot point is adjusted two years after the trigger has been realised (see next row).
Trigger point	The trigger point is a specified condition which determines (in combination with the lead time) the moment at which the current pivot point is shifted. It is defined as the relative distance to the current pivot point. For most metrics, this value will generally be negative. In the example shown in Figure 12 (for gCO_2/km) , the pivot point adjustment is triggered if average fleet emissions are 1% lower than the current pivot point. You could also set a positive value in order for the trigger point to be set at a value between the current average emissions and the current pivot point. In this case the trigger is activated sooner than in case of a negative value for the trigger point. Finally, if you set the trigger point at a large positive value, which is already higher than the current average emissions, the trigger is immediately activated. A positive value for the trigger point results, in most cases, in a net revenue stream to the government. Therefore, positive values should not be chosen when a revenue neutral scheme is desired. For the metric 'fuel economy – distance/volume' the reverse logic holds: the metric is expected to increase over time and therefore this trigger point will generally be positive, but also small negative values may work correctly. In case large negative values are chosen, the function will not work correctly anymore and the tool will warn you.
Relative change in the pivot point	This parameter is the pre-determined criterion by which the pivot point is adjusted (after the lead time) once the trigger point is met. In the example shown in Figure 12, the pivot point is set 6% lower. In case the metric CO_2 emissions or fuel economy – volume/distance is chosen this parameter is always negative. On the other hand, in case the metric 'fuel economy -distance/volume' is chosen, the metric is expected to increase over time, and hence, the relative change is a positive value.

Figure 12   Choosing a pivot point and its adjustment: Lagged adjustment based on trigger

Restrictions with step-based functions.
Note that if you choose a step-based function in the rebate function shape control panel (Section 3.4), the only available pivot point control option is 'manual pivot point adjustment' as it is very difficult with such function shapes to adjust the pivot point in such a way that it will fulfill certain criteria (e.g. revenue neutral system). If you want to disable this restriction, go to 'advanced design options' – 'other options' and check the box circled red in Figure 13. Hereafter go back to the Design (green circled button) and click on the 'Update' button in the Rebate Function Shape Control.

Figure 13   Disabling restrictions on pivot point control with step-based function

3.3   Metrics and units

The metric of the feebate system determines the type of vehicle performance that is measured to calculate the feebate amount. The default option is the CO_2-based metric, which has the main advantage that it is fuel-neutral; it automatically takes into account any differences in the CO_2 emissions of different transport fuels.

More detailed background information on the various feebate metrics and their pros and cons

In the tool you can choose for two main types of metrics – a CO_2-based metric (gCO_2/km) or a fuel economy metric (l/100 km or km/l), by selecting one of these options from the 'Metrics' drop-down menu in the upper right corner of the 'feebate design' tab (see Figure 14, green circle). If you select 'fuel economy', a new drop-down menu appears where you can choose for a fuel economy metric that is based either on volume/distance (l/100 km) or on distance/volume (km/l). When you have selected the metric of your choice, you need to click on the 'Update' button to incorporate the changes made in the rest of the feebate design panel.

Irrespective of the metric you choose, the tool allows you to change from kilometres and/or litres to miles and/or gallons with the drop-down menus in the units section shown in Figure 14 (red arrows). Again, you have to click on the 'Update' button to incorporate the changes made in other sections of the feebate design panel.

Figure 14   Choosing a metric and unit

3.4   Rebate function shape control

In the 'Rebate Function Shape Control' (see Figure 15), you can determine a basis for the rebate function (i.e. shape) of your feebate system by selecting one of the five options from the drop-down menu of shape examples (red circle in Figure 15):
− linear;
− linear piecewise;
− step-based with uniform steps;
− step-based with uniform steps;
− design your own.
The default option is a linear function, as this provides a continuous incentive to improve each vehicle (in contrast to step-based functions which only incentivise vehicles located near a step).

By selecting one of the options in the drop-down menu, the graph at the right hand side of Figure 15 will change accordingly.

Figure 15   Rebate function shape control
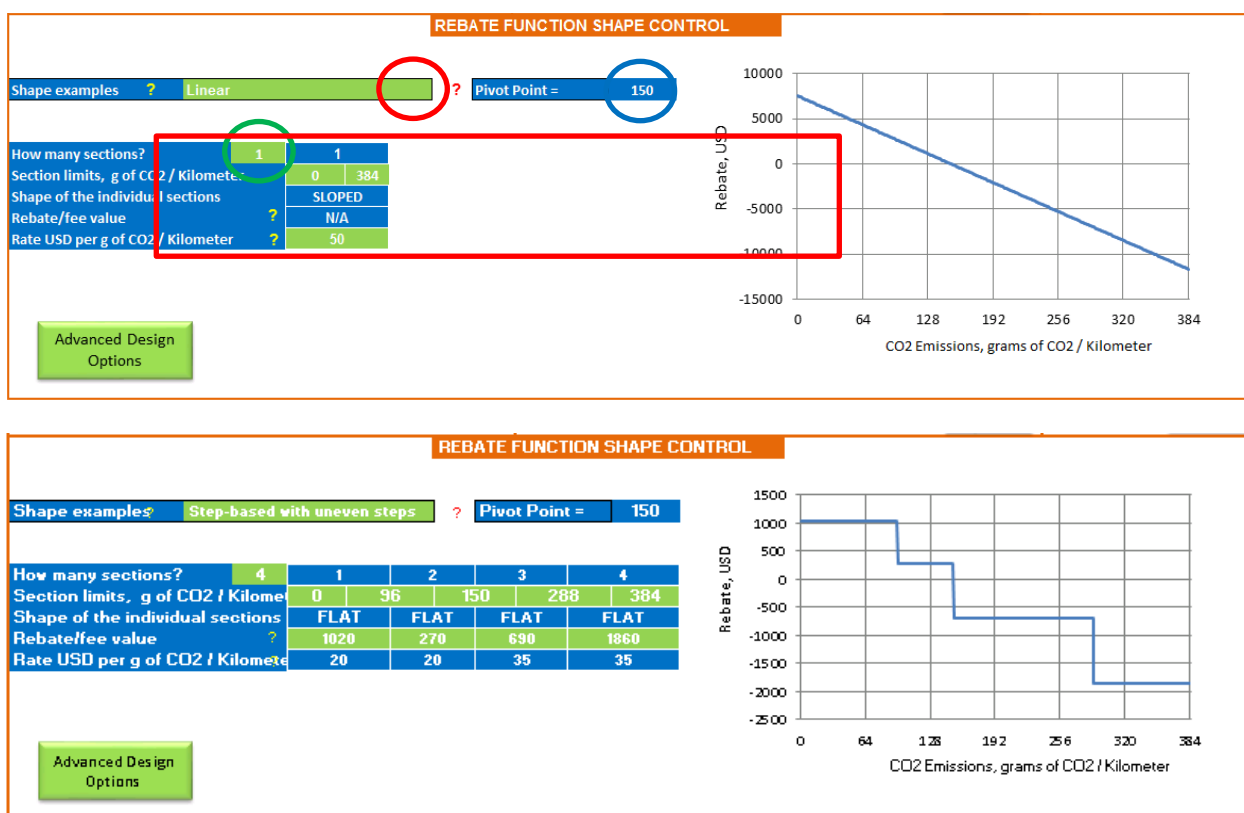
After selecting an initial shape for the rebate function, you start with fine-tuning it by adjusting the values in the table (red rectangle in Figure 15). As indicated by the blue and green cells, you cannot change all values when you have chosen a pre-defined option (e.g. you cannot choose for a flat section when you have chosen a linear function, as with a linear function, the function is sloped by definition). If you would like to change such blue cells, you can select the 'Design your own' option from the drop-down menu, which does allow you to deviate from regular feebate designs (e.g. by combining flat and sloped sections).

Table 5 explains the user's options for fine-tuning the rebate function design for each row of the table shown within the red rectangle of Figure 15.

Table 5   Fine-tuning the rebate function

Aspect to customise	Action
How many sections?	Determines the number of sections. The different sections of the rebate function allow the user to set different values (e.g. rate per gCO_2/km) for each section. When clicking on the drop-down menu in the green cell of the first row (green circle in Figure 15), the user can adjust the number of sections. Note that this is only possible when you have chosen for the 'design your own' option. In this case, you can choose a number of sections ranging from 1 to 4. For the other design options, the number of sections is pre-determined.
Section limits	Determines the range of performances that fall within a section. In the example shown in Figure 15 (second row of the table in the red rectangle), Section 1 runs from 0 to 96 g of CO_2/kilometer, Section 2 from 96 to 192 g of CO_2/kilometer, and so on. You can change the values by clicking on the cell you want to adjust and by overwriting it with a different value.
Shape of the individual sections	Determines whether a section is sloped or flat. If you would like to change this design aspect, you need to select the option 'design your own' from the drop-down menu. Then you can select a flat or sloped section from the drop-down menus in the third row of the red rectangle.
Rebate/fee value	Determines the fee or rebate for a car that falls within a section limit of a flat section. You can change the amount by overwriting the values in the fourth row with other values. The value you insert is the entire amount of the fee/rebate for a car that falls in that section (in USD) (e.g. a car with 64 gCO_2/km falls in Section 1 and therefore pays 1,020 USD).
Rate USD per…	Determines the rate of the feebate for a sloped function. You can change the values by clicking on the cell in the fifth row that you want to adjust and by overwriting it with a different value. The value you insert is in USD per metric (e.g. USD per gCO_s/km or USD per l/100 km). The total amount of the rebate given is calculated by multiplying this rate with the difference between the pivot point and the performance of the car (e.g. in this case, a car with 64 gCO_2/km receives (150 -/- 64) * 50 USD per gCO_2/km = 4,200 USD).

Note that the pivot point (blue circle in Figure 15) is determined with the choices you have made in the pivot point control panel. For the two annual adjustment options you cannot change this value as the tool determines the required pivot point automatically. For the other two options from the pivot point control panel (lagged adjustment based on trigger and manual pivot point control) this value can be adjusted by the user.

3.5   Advanced controls

Tab: 'Feebate Design' – 'Advanced Design Options' button
Actions: If desired, the user can change some of the underlying assumptions of the tool
More information: mainly **Annex D**, **Annex C.6 and C.7**.

By clicking on the 'Advanced Design Options' button in the lower left corner of the 'Feebate Design Options' tab you can change some of the underlying assumptions of the feebate simulation tool. All these aspects have default values, so there is no need to change these aspects if you do not have sufficient data or knowledge to do so. Advanced control options are discussed in the following in detail.

3.5.1 Budget control

Here you can change the point of administration of the feebate system. As a default, the feebate is administered at the manufacturer (incl. distributors of new and second-hand vehicles) level, as this is easier to implement and less expensive than the consumer level. However, you can change the point of administration by selecting the consumer level option in the drop-down menu (see green circle in Figure 16).

> *More detailed background information on the point of administration and the pros and cons of both options can be found in Annex C.7.*

The tool also incorporates estimations of the average administrative costs of a feebate system (red circle in Figure 16). The default values are based on the Californian feebate scheme (Bunch & Green, 2010). However, if you have specific information or knowledge on the likely administrative costs for your country, you can change these assumed administrative costs. To do so, click on a value within the red circle and overwrite it with a new value (in % of average fees and rebates).

Figure 16   Adjusting the budget assumptions

Finally, if you have added a new country to the tool (in the 'Input Data' tab), you have to enter the exchange rate of your country in this tab, by overwriting the values in the empty row(s). More information on this aspect can be found in Section 2.2.

3.5.2 Manufacturer behaviour
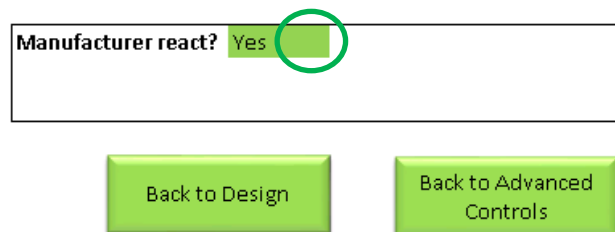
In this panel, you can change the assumption made on whether manufacturers (incl. distributors of vehicles) react to the implemented feebate system or not. The tool assumes that manufacturers and, in case of transition and developing countries, distributors in particular, will react to the feebate system. This assumption implies that they will be incentivised to improve the fuel economy/reduce the CO_2 emissions of the vehicles they manufacture, sell, and/or import.

> *More detailed background information on the assumed manufacturer behaviour can be found in Annex D.*

If you want to explore the effects of a feebate system in case manufacturers do not react, you can change this default by selecting 'No' from the drop-down menu shown in the manufacturer behaviour control panel (green circle in Figure 17). This however, is unlikely to be the case in reality.

Figure 17   Changing the assumptions on manufacturers' behaviour

3.5.3 Consumer behaviour

In the consumer behaviour control panel you can change the assumptions made in the tool on the price elasticity[1] of consumers. The tool incorporates assumption on consumers' price elasticity at four decision levels shown in Figure 18, ranging from a relatively low elasticity to a relatively high elasticity)

− purchase decision: choice between acquiring a car or not;
− groups: choice for a particular type of car (e.g. medium or small);
− segments (choice for a car within a segment, e.g. lower medium, medium, upper medium);
− sub-segment (choice for a car within a small sub-segment, e.g. within lower medium cars).

---

[1]   A parameter which denotes the price sensitivity of consumers with respect to the purchase price of cars.

> *More detailed background information on the assumed consumer behaviour can be found in Annex D.*

The values shown in Figure 18 are defined as the percentage decrease in demand when the price increases with 1%. Hence, the 0,4 indicates that a price increase of 1% results in a decrease of demand of 0,4%. You can change the assumptions on price elasticity of consumers by overwriting the default values in the green cells of the consumer behaviour control panel.

Figure 18   Changing assumptions on the elasticity of consumers

CONSUMER BEHAVIOUR CONTROL PANEL

Elasticity of substitution for: ?		Reset Values
	0	
Purchase decision	0,4	
Groups	1,5	
Segments	2,0	
Sub-segments	3,5	

Back to Design   Back to Advanced Controls

3.5.4   Attribute adjustments

In this panel, the feebate system can be designed with an adjustment of the fees and rebates to particular attributes (i.e. vehicle characteristics), such as vehicle size, vehicle weight, etc. With an attribute adjustment, the fees/ rebates for two vehicles with the same performance (in terms of the metric chosen, e.g. gCO_2/km) can be adjusted if they differ on the specific attribute (e.g. if one is larger than the other and the attribute chosen is size).

> *More detailed background information on attribute adjustments and the pros and cons of the options can be found in Annex C.6.*

In the tool, three attribute adjustments can be chosen, as shown in Figure 19. The default version of the tool does not incorporate any attribute adjustments. To enable one of the attribute adjustments, you can select 'enable' from one of the drop-down menus (green circles). When looking at the attribute adjustments that have been included in the tool, the vehicle size-attribute is relatively most beneficial, followed by a weight adjustment. The attribute engine power can actually have harmful effects (i.e. will increase emissions) and is therefore not recommended. This is further described in Annex C. Box 2 describes how the attribute adjustment is calculated in the tool.

Box 2   **Modelling attribute adjustment**

Attribute adjustment in the tool

Consider the following example:

–   car with 60 gCO_2/km and a weight of 1,600 kg;

–   linear rebate function with a rate of 30 USD per gCO_2/km;

–   pivot point 150 gCO_2/km;

–   attribute adjustment of vehicle weight, average weight of the country's fleet is 1,800 kg;

–   flat rate: 0,6

Without attribute adjustment the rebate would be: 150 * 30 -/– 60 * 30 = USD 2,700)

With the attribute adjustment the rebate is: **(150*(1+0.6*(1600-1800)/1800) – 60) * 30 = 2.400 USD.**

The flat rate can be adjusted by the user. It is a correction for the fact that the relationship between fuel economy or CO_2/km and the chosen attribute (e.g. weight) is not linear. The higher the rate, the stronger the relationship between the metric and the attribute assumed, and the larger the impact of the attribute adjustment on the fees and rebates. The European CO_2 regulations assume this factor is 60%, therefore this is set as the default value in the tool.

After enabling an attribute adjustment, the user can decide whether to change the flat rate of 60% (see Box 2) by overwriting this default value for the particular attribute with another value.

Figure 19   Including an attribute adjustment in the feebate system

4 Results of feebate system

Once you have designed your feebate system and run the tool you can check the results for your (default) country by navigating to the tab 'Results' (red circle in Figure 20) or by clicking on the 'View results' button in the upper left corner of the feebate design tab. This tab first shows a policy summary (blue rectangle), which is an overview of the main design options you have chosen in the previous step and the resulting pivot points for the different years.

Hereafter, vehicle and financial impacts are shown (see the next sections). At any time, if you are not satisfied with your design (and/or the results of your design) you can adjust your feebate system by clicking on the button 'Back to Design' (circled green in Figure 20) in the upper right corner of this tab. If you decide to change design elements you need to run the tool again ('Run' button) and go back to results ('View results' button).

If you are satisfied with your results, you can click on the button 'Copy results'. A new tab will be generated with the results of your design. Hereafter you can try different designs without loosing the results of previously generated (saved) results. You can delete the tabs with saved results by clicking the button 'Delete Saved'. Both buttons are located in the upper right corner of the 'Results' tab.

Figure 20   Screenshot of results tab in feebate tool
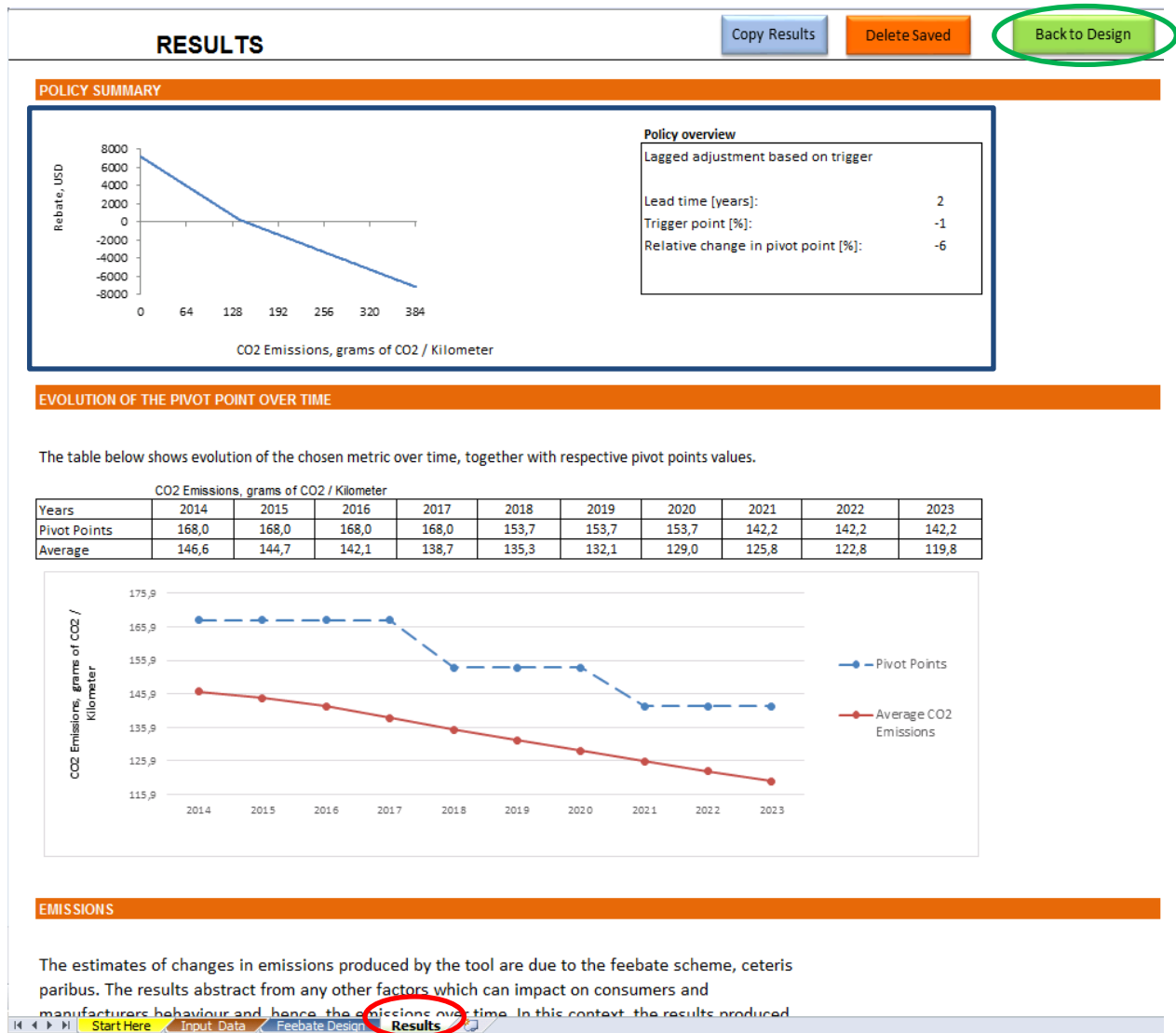
4.1   Evolution of the pivot point over time

Under the orange heading 'Evolution of the pivot point over time' (see Figure 20) the evolution of both the pivot point and the average CO_2 emissions over time are shown.

Notice that in case the pivot point control mechanism 'lagged adjustment based on trigger' is chosen, the resulting evolution of the pivot point over time (as shown under this heading) doesn't match with the 'relative change in pivot point' chosen in the pivot point control panel (on the tab 'Design'). That is because the latter is the relative change of the pivot point compared to the pivot point that is applied in the year the trigger it activated, while the former presents the relative change of the pivot point compared to the initial pivot point.

4.2 Impacts on vehicle fleet

The impact of the designed feebate system on the vehicle fleet of your selected country is shown both graphically and in a table under the orange heading 'Emissions' (see Figure 21). The blue line with yellow diamonds in the graph shows the reduction in the average emissions from newly-registered cars (left scale). The green and red bars in the graph show the share in the reduction of emissions that result from manufacturers offering more efficient cars (green) and from consumers choosing for a more efficient car (red). The relative change these groups have caused can bee found in the right scale. The table below the graph shows the same information quantitatively.

Figure 21   Impact feebate system on vehicle fleet

Year	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
Average emissions from newly registered vehicles (CO_2 level)	146,6	145,4	143,6	141,1	139,0	136,8	134,6	132,3	129,9	127,2
Change in average emissions (year-on-year)	0,0	-1,3	-1,8	-2,5	-2,1	-2,2	-2,2	-2,3	-2,4	-2,7
Consumers contribution to year-on-year CO_2 change	0,0	-0,7	-0,7	-0,7	-0,7	-0,8	-0,8	-0,8	-0,9	-0,8
Manufacturers contribution to tear-on-year CO_2 change	0,0	-0,5	-1,1	-1,7	-1,4	-1,4	-1,5	-1,5	-1,5	-1,8

4.3 Financial impacts

Under the next orange heading 'Budget' the financial impact of the designed feebate system on the governmental budget is summarised (see Figure 22). The orange shaded area shows the paid rebates, whereas the blue shaded area represents the fees that have been charged. The yearly net balance of paid rebates, received fees and of administrative costs of the feebate system is depicted by the blue line ('Governmental balance').

Again the table summarises the same information as the graph quantitatively. However, the bottom row shows some additional information: the 'cumulative governmental balance', which is the (aggregated) total impact for the whole period.

Figure 22   Financial impact of feebate system on governmental budget

Fiscal balance of the simulated feebate system, millions USD

Year	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
Rebates	-645,1	-651,0	-647,6	-636,9	-622,8	-606,2	-587,8	-568,6	-549,5	-559,4
Fees	649,7	655,5	652,1	641,4	627,2	610,6	592,1	572,5	553,3	563,2
Administrative costs	-4,6	-4,6	-4,5	-4,5	-4,4	-4,3	-4,3	-3,9	-3,9	-3,8
Governmental balance	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Cumulative governmental balance	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0

Annex A Introduction to feebate systems

A.1 Introduction

This annex provides some more detailed background information on feebate (-like) schemes. Firstly, the general characteristics of feebate schemes and feebate-like schemes are described in Section A.2 and A.3, respectively. In Section A.4 a comparison is made between feebates and other policy instruments. A summary of feebate (-like) schemes that have been implemented worldwide is presented in Annex B.

A.2 General description of feebate schemes

The basic principle of any feebate system is that fuel-efficient cars with low CO_2 emissions per km receive a rebate, while a fee is imposed on fuel-inefficient ones with high CO_2 emissions per km. In order to determine what classifies as an efficient or inefficient car, a pivot point (also referred to as a 'yardstick' or 'benchmark' in literature) is needed (Peters et al., 2008; Greene et al., 2005; ICCT, 2010). This pivot point can for example be defined with a particular CO_2 emission level (e.g. gCO_2/km), fuel consumption level (e.g. l/100 km), or other feebate metric. The pivot point that is set then determines whether a vehicle receives a rebate (i.e. scores better than the pivot point) or is charged a fee (i.e. scores worse than the pivot point).

In Figure 23, this basic principle of a feebate system is shown graphically.

Figure 23   **Basic principle of a feebate system design (for two different types of feebate functions)**
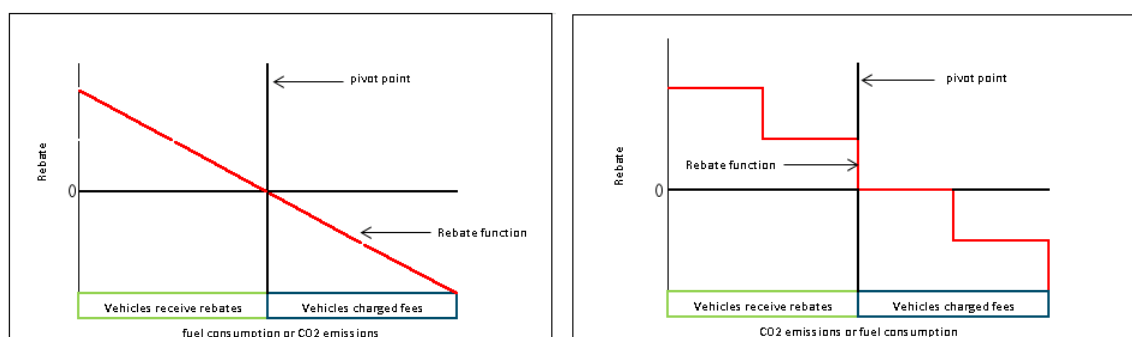
a) feebate with continuous feebate function   b) feebate with even step-based feebate function

Source: ICCT, 2010, adjusted by CE Delft.

The pivot point does not (directly) influence the fuel-efficiency improvements that will be realised with the system, as this is mainly determined by the slope of the rebate function (i.e. the slope of the red line in Figure 23, also referred to as the 'feebate rate', which influences the strength of the incentive given). The pivot point does influence the cost-revenue distribution between the market (i.e. total group of consumers/manufacturers) and the government, as it determines who pays fees and who receives rebates (Greene et al., 2005). If the pivot point is set appropriately, it will balance the fees and rebates. In this case, the fees received can be used to pay the rebates, which results in a budget-neutral system. However, policy makers can also choose to set a pivot

point that results in net revenues to the government. In order to ensure the continuation of the cost-revenue distribution that is chosen, it is necessary to adapt the pivot point with the fuel-efficiency improvements in the new car fleet (ibid.). This can be accomplished continuously or with fixed periods and can be based on observations or pre-determined criteria for example. Especially for developing countries, setting the right pivot point and choosing an appropriate system for adjusting this pivot point are extremely important, as these countries will have less resources to deal with unexpected revenue shortfalls.

The feebate system will cause the fuel-efficiency of the car fleet to improve, by providing an incentive to manufacturers to improve their cars (Greene et al., 2005) and/or by providing a price signal to consumers to buy more fuel-efficient cars (Peters et al., 2008). The larger the distance between the vehicle's performance from the pivot point, the higher the fee or rebate (ICCT, 2010). Obviously, the steeper the slope of the feebate rate, the higher the incentive will be to improve performance or to buy a more efficient car as it will result in higher benefits (i.e. higher rebate or lower fee by improving one step). The feebate rate therefore mainly determines the efficiency improvements that will be obtained with the feebate. Another factor of influence on the overall efficiency improvements obtained is the feebate function design (see Figure 23). A continuous feebate function provides an incentive to improve every vehicle, while a step-based function only provides an incentive to improve vehicles close to a step.

The incentive provided to car manufacturers to improve performance is argued to be much larger than the incentive provided to consumers to buy a more efficient car (Greene et al., 2005; Davies et al., 1995). According to Greene et al. (2005), 87%-96% of the fuel-efficiency improvements (depending on the chosen parameters) result from the adoption of fuel-saving technologies by manufacturers, not from changes in the vehicle mix that is sold due to changes in consumer choices. Davies et al. (1995) found similar results and report that only 10% of the improvements are due to this latter mentioned aspect. In developing and transition countries, which import rather than produce most vehicles, these shares may be different (i.e. larger share for consumer reactions). This is important to keep in mind when choosing the point of administration of the feebate, which can be administered at the manufacturer or consumer level. However, there will always be (at least some) interaction between what manufacturers offer and what consumers demand; if consumers are not willing to pay a premium for a highly efficient car, the manufacturer is unlikely to offer it. In general, shifts in vehicle sales mix may be larger when an attribute adjustment is applied for the feebate, setting different pivot points for different categories (e.g. vehicle sizes, fuel types, etc.).

As becomes clear from the general feebate description above, there are many choices that have to be made when designing a feebate system (e.g. for the feebate metric, feebate function, feebate pivot point, etc.). Annex C will describe each of these choices in more detail.

A.3 Feebate-like schemes

There are several design options that do not have all feebate characteristics described in the previous section, but that do have one or more feebate-like aspects. These are often referred to as fee-only or rebate-only programs (ICCT, 2010). An example of a fee-only system with a step-based fee function is shown in Figure 24. If the slope of the fee or rebate is comparable to that of a feebate system, the fee-only or rebate-only provides the same incentive to improve the vehicle fleet. However, the main difference with a feebate system is that these systems are not budget-neutral (ibid.). If the fees (or rebates) are not adjusted continuously, governmental revenues will decrease (or expenditures will increase) as the vehicle fleet becomes more efficient.

Figure 24   Fee-only system with an even step-based fee function
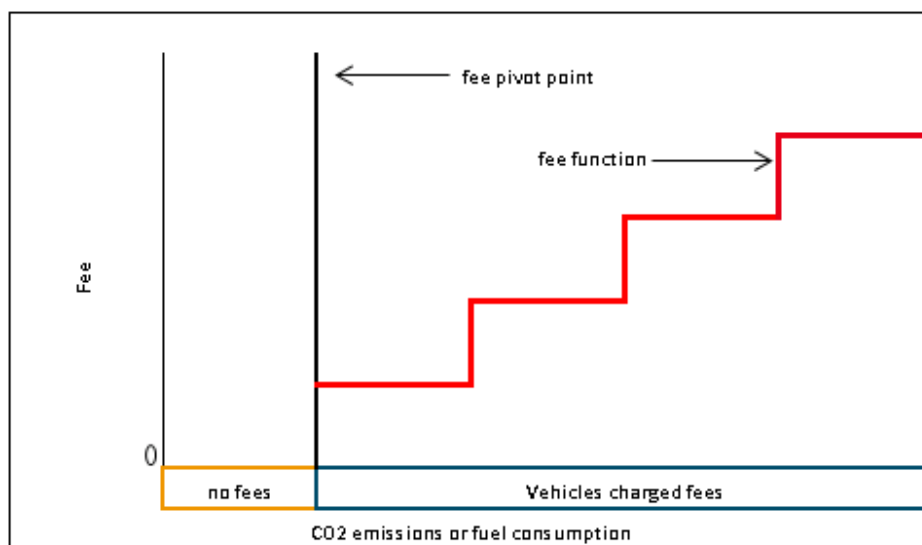
Several countries (e.g. The Netherlands, Denmark, Ireland, Germany, the UK, the US, and Sweden) have implemented differentiated vehicle tax systems. In these countries, the purchase tax and/or the annual ownership tax are either totally or partially based on the fuel consumption or CO_2 emissions of the vehicle (ICCT, 2010). These programs provide examples of fee-only systems and are further elaborated on in Annex B.

A.4 Feebate systems vs. other policy instruments

Policy makers can implement several other instruments to reduce the CO_2 emissions of new passenger cars, such as standards or taxes. The following sub-sections compare feebates with such other instruments and describes how these policy instruments could strengthen each other.

A.4.1 Feebates vs. vehicle standards

Many developed countries (e.g. the EU, US, Japan, South Korea) have implemented CO_2 standards for passenger cars. CO_2 standards are a mandatory instrument that obligates car manufacturers to comply with a given target; the relative emission reduction goals that have been set will therefore be reached with certainty, although the absolute emission reduction also depends on the amount of kilometres driven. The fact that the relative emission reduction is

obtained with certainty, is an important advantage of standards as compared to measures that provide an economic incentive, including feebates (TEPR & TNO, 2012). Rebound effects that may reduce the absolute amount of emissions reduced (e.g. increased amount of kilometres driven) can then be targeted with other instruments (e.g. fuel taxes) (ibid.).

With providing economic incentives (e.g. taxes, feebate schemes), similar results may be obtained, but this is much more uncertain as there may be several market failures preventing consumers or manufacturers to react rational, which may hamper the targeted emission reductions (TEPR & TNO, 2012). However, although feebate systems do not fix the emission reduction that will be obtained, they do fix the costs of the realised decrease in emissions (with the feebate rate function) (ICCT, 2010). These costs are not fixed when implementing vehicle standards (ibid.). So although both feebate schemes and vehicle standards result in the adoption of fuel-saving measures that improve the energy-efficiency of vehicles, they differ in the certainty they provide: feebate schemes provide certainty on the costs of emission reduction, while vehicle standards provide certainty on the level of emission reduction that will be obtained. Another difference between both instruments is that feebate systems provide a continuous incentive for improving fuel-efficiency, whereas standards only provide an incentive to improve efficiency up to the point where the standard is met. After this point manufacturers will have no additional incentive to further increase the fuel-efficiency levels of their vehicles (Greene et al., 2005). At this point, feebates and standards can strengthen each other; the standard ensures that a minimal efficiency level is obtained, while the feebate would give manufacturers an incentive to improve performance beyond what is required by the standard (ICCT, 2010).
In addition, feebates can help manufacturers in reaching the standard's targets, as such economic instrument also influence the energy-efficiency of vehicles (TEPR & TNO, 2012). This may enlarge the social acceptance of the standards in the long-term.

Another argument that can be made to implement standards in combination with feebates relates to the low value that most consumers seem to attach to future fuel savings. Due to the fact that there are many uncertainties with respect to the future revenues that may result from fuel savings, consumers use extremely high discount rates and as a result place a low value on such savings (Greene et al., 2005). Consequently, consumers may not (fully) value the fuel-efficiency improvements that were made by manufacturers to comply with the standard, which will lower their demand. Feebates partially resolve this market imperfection, by giving an upfront payment for future revenues from fuel savings, this places immediate value on the technologies that were adopted to improve the fuel performance of vehicles and will increase their demand (ICCT, 2010).

In order to implement a vehicle standard, a lot of information is required; in-depth knowledge of the vehicle fleet, the current and future technologies, the costs and benefits of these technologies, and the time it will take to implement them. This information should be combined with models to determine what the expected impact of all these factors will be; the standard should be based on this result (ICCT, 2010). Many developing countries will not have (all) this data available, nor will they have appropriate models. This will likely hamper the implementation of standards in these countries. In this light, feebates may offer an advantage over standards; feebate systems can be implemented with technical knowledge (e.g. knowledge on the fleet and the future offer from manufacturers) that is relatively easier to obtain and may therefore be easier to implement in developing countries (ICCT, 2010).

However, feebates will also require information, for example on the fuel-efficiency and market shares of the vehicles sold.

A.4.2   Feebates vs. fuel taxes

Most countries levy at least some taxes on transport fuels sold. These taxes provide a strong incentive for vehicle owners to purchase more fuel-efficient cars on the one hand, and to reduce the kilometres travelled on the other (Greene et al., 2005). Further increasing fuel taxes would strengthen these effects. However, two factors may counteract the effectiveness of this measure.

Firstly, there are some studies that indicate that consumers are not completely rational when it comes to the value they place on future fuel savings, which is relatively low as there are many uncertainties with respect to future fuel prices and taxes (Greene et al., 2005). In this case, the incentive for buying fuel-efficient cars would be lower as well (ibid.). Feebates on the other hand, partially solve this market failure by providing an upfront payment for the future revenues that can be obtained from fuel savings (ICCT, 2010). As the upfront payment can be obtained immediately and with certainty, this is likely to result in a larger incentive to buy a fuel-efficient car than if the consumer had to base its decision on the uncertain revenues of future fuel tax savings.

Secondly, increasing fuel taxes is quite an unpopular measure and has resulted in a lot of public opposition in the past, which may impede this measure from being taken (ibid.). Feebates will have similar effects in terms of stimulating the choice for fuel-efficient vehicles and may therefore provide an alternative to (increasing) fuel taxes; this measure may result in less public opposition as rebates are given as well, especially when the system is administered at the manufacturer level where it may be largely invisible to consumers.

However, as feebates (and standards as well) will result in a more efficient vehicle fleet, this will also reduce the costs per travelled kilometre, which in turn may result in more travelling (and hence, more emissions).
Put differently, feebates and standards may result in a rebound effect (Boutin et al., 2010). At this point, (increasing) fuel taxes can complement the feebate/standard to reduce this rebound effect by increasing the costs per kilometre travelled and hence, reducing the incentive to travel more.

A.4.3   Feebates vs. vehicle purchase and ownership taxes

Two main types of vehicle taxes have been implemented in developed countries; purchase taxes that are levied once, at the point of purchase, and ownership taxes that are usually levied annually. The tool only covers this first-mentioned tax, but this does not imply that feebates cannot be implemented on ownership taxes as well.

Vehicle taxes and feebates share many similarities, especially when the vehicle taxes are differentiated by fuel consumption performance or similar metrics. Both measures use an economic incentive to stimulate particular behaviour. However, while vehicle taxes provide the government with a net income (without risking shortfalls), feebates can be budget-neutral or provide a net income to the market by giving rebates (with risks of shortfalls) (ICCT, 2010). The fact that feebates also provide rebates to stimulate the desired vehicles may result in a higher level of public support than a tax-only system (Greene et al., 2005; du Plooy & Nel, 2012).

A study of D'Haultfoeuille et al. (2010) showed that consumers reacted 20 times more sensitive to the rebate than to regular price changes, although they could not conclude what caused this sensitivity. It may be explained by consumers attaching more value to environmental concerns as a result of the feebate, or by increased marketing efforts of manufacturers they argued. Irrespectively of what caused this high level of sensitivity, it implies that feebates may be more effective than if a purchase tax has been implemented, although the number of studies reporting such results is limited.

If a feebate is implemented for the purchase tax, the system provides a price signal at the point of purchase. An ownership tax on the other hand provides a price signal on a yearly basis. Therefore, the ownership tax complements and strengthen the feebate on vehicle purchases, especially if the ownership tax would be differentiated by the CO_2 performances of the vehicle. In this case, the price signal would be given both at the point of purchase and on a yearly base hereafter, which is likely to result in larger effects.

Annex B Examples of implemented feebate(-like) systems

This annex provides a detailed overview of the feebate (-like) systems that have been implemented in France (Section B.1), The Netherlands (Section B.2), Canada (Section B.3), Ireland (Section B.4), the US (Section B.5), Germany (Section B.6), Sweden (Section B.7), and the UK (Section B.8). Section B.9 summarises these country results. Where available, data on the effectiveness of these systems is described as well.

B.1   French bonus-malus policy on new vehicle sales

In January 2008, the French government has implemented a feebate system for new vehicle sales (D'Haultfoeille et al., 2010). The French feebate charges a fee (malus) to vehicles with CO_2 emissions over 160 g/km, while providing a rebate (bonus) to vehicles with CO_2 emissions lower than 130 g/km. As is shown in Table 6, the French feebate system makes use of a step-based feebate function to determine the feebate amount. I.e. the feebate amount is set for different CO_2 performance categories.

Table 6   Summary of the French feebate system at the point of implementation (2008)

Class of emissions	Emissions (g/km)	Malus in €$_{2008}$
A+	<60	-5,000
A	60-100	-1,000
B	100-120	-700
C+	120-130	-200
C-	130-140	0
D	140-160	0
E+	160-165	200
E-	165-200	750
F	200-250	1,600
G	>250	2,600

Source: D'Haultfoeille et al., 2010.

Table 6 shows that the French feebates uses the metric 'gCO_2/km' to operationalise the system; the rebate pivot point lies at 130 g/km, while the fee pivot point is set at 160 g/km. Vehicles in between receive no fee or rebate. With the implementation of the system, it was determined that the CO_2 emission categories would be lowered with 5 gCO_2/km semi-annually, which was the anticipated improvement of the vehicle fleet (Bastard, 2010). Therefore, this pivot point is adjusted semi-annually with fixed, pre-determined criteria.

When plotting the feebates graphically (see Figure 25), it becomes evident that the French feebate step-based function is uneven, both in terms of the emission class bandwidths defined (g/km) as well as in terms of the steps in the feebate amount. This will provide different incentives for different vehicle performances. In general, manufacturers will mainly have an incentive to

improve performance of those vehicles that are close to a step, as a lower fee or higher rebate may result.

The ICCT (2010) has estimated the slope (in € per g/km) of the step-based feebate function and concluded it is approximately - € 18.1 per g/km for vehicles with CO_2 emissions ranging from 60 g/km up to 250 g/km. Note that the slope of vehicles that emit less than 60 g/km or more than 250g/km is zero. Consequently, manufacturers will have no incentive to improve performance beyond the 60g/km performance level, nor to improve performance of vehicles with emissions over 250 g/km, except for those that are close to this pivot point (and hence, can obtain a lower fee).

Figure 25   Overview of the French feebate system
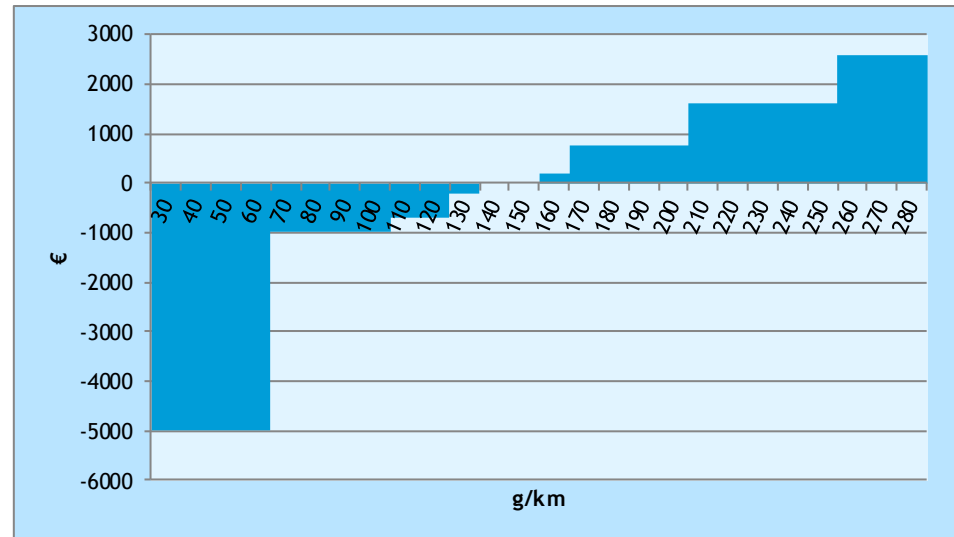
Several studies have evaluated the impact of the French feebate. Observations of the French car sales show a significant shift to the more efficient vehicle classes; the shares of vehicles with 60-100 and 100-120 g/km increased with 436% and 131%, respectively, while the shares of vehicles with 200-250 and >250 g/km fell with 58.8 and 59.7%, respectively (D'Haultfoeille et al., 2010).

The average CO_2 emissions of new vehicle sales in France decreased from 148.4 g/km in 2007 to 139.7 g/km in 2008; a reduction of 9 g/km (Klier & Linn, 2012; Bastard, 2010). According to Klier & Linn (2012), 7.95 g/km (91%) of this observed reduction in average emissions is a result of the bonus-malus policy. This implies that the bonus-malus policy resulted in a 5.5% decrease in the emission factor of newly sold vehicles. Bastard (2010) and D'Haultfoeille et al. (2010) have found roughly comparable results and report that emission factors decreased with 6 and 5%, respectively.

The French feebate system was designed to be budget-neutral, however, the feebate resulted in total costs of slightly over € 200 million in 2008 and of € 500 million in 2009 (Bastard, 2010). According to D'Haultfoeille et al. (2010), this resulted from the fact that the estimated effects could not be explained by price variations and elasticities alone; consumers were approximately 10 times more sensitive to the bonus/malus than to regular price variations. It is unclear what has caused this large sensitivity, but possible explanations may be the increased environmental concerns as a result of the feebate or increased advertising by manufacturers.

B.2 Dutch bonus-malus policy on new vehicle sales

From 2006 to 2010 the Dutch government has implemented a feebate system in the Netherlands. The purchase tax on new vehicles was differentiated according to the energy label of a vehicle, which is summarised in Table 7. The feebate provided vehicles with a B label or better a bonus (rebate), while those with a D-label or worse were charged a malus (fee) (PBL, 2009).

The feebate metric used to operationalize the feebate system was the energy label of the vehicle therefore. The Dutch energy label of a vehicle determines the relative energy efficiency of this vehicle as compared to other vehicles in the same size class (PBL, 2009). Although vehicles with the same energy label performance received the same feebate, it may have occurred that vehicles that performed differently in terms of CO_2 emissions/fuel consumption received the same feebate. The feebate function can be considered (uneven) step-based in nature, as each energy label covers a range of relative fuel-efficiency and the steps in feebate amount are not uniform.

Table 7 Dutch bonus-malus policy in 2006-2008 and 2008-2010

Energy label	Fuel-efficiency	Malus since 2006 in €	Malus since 2008 in €
A	>20% more fuel-efficient than others in size category	-1,000	-1,400
B	10-20% more fuel-efficient than others in size category	-500	-700
C	0-10% more fuel-efficient than others in size category	0	0
D	0-10% less fuel-efficient than others in size category	135	400
E	10-20% less fuel-efficient than others in size category	270	800
F	20-30% less fuel-efficient than others in size category	405	1,200
G	>30% less fuel-efficient than others in size category	540	1,600

Source: PBL, 2009, adapted by CE Delft.

The bonus-malus policy has been evaluated ex-post in three studies. The vehicle sales data in the Netherlands shows that the average fuel-efficiency of the new vehicle sales improved with 1% per year (PBL, 2009). According to PBL (2009), only 20% of this yearly improvement has resulted from the bonus-malus policy. The intensification of the system in 2008, resulted in an additional 0.1-0.2% improvement they argue (ibid.). CE Delft (2008) on the other hand, estimates the effect of the bonus-malus (2006 fees and rebates) on 0.3–0.5%. The third study, conducted by MMG Advies (2008), reports the highest effectiveness and state that the bonus-malus policy has been responsible for 0.5-1% of the improvement in fuel-efficiency.

The bonus-malus system was designed to be budget-neutral, but actual costs were 42 million euros in the first one and a half year of the system (CE Delft, 2008).

Currently, the Dutch feebate system has been replaced by a fee-only system.

B.3 Canadian EcoAUTO and Green Levy Program on new vehicle sales

The Canadian government implemented two short-term programs simultaneously in 2007, which together had the characteristics of a feebate system. The rebates and fees of both programs are summarised in Table 8. The feebate metric chosen for both programs was based on fuel consumption (l/100 km).

The ecoAUTO program provided rebates to new passenger cars and to light trucks (vans, SUVs, etc.) with a fuel consumption of 6.5 l/100 km (166 gCO_2/km) and 8.3l/100 km (216 gCO_2/km) or less, respectively. As different pivot points were defined for two vehicle types, the rebate was an attribute-based system. The Green Levy Program on the other hand, charged a tax to passenger vehicles that consumed 13 l/100 km (350 gCO_2/km) or more.

Table 8   Canadian ecoAUTO and Green Levy Programs

Fuel consumption (l/100 km)	Rebate (ecoAUTO)		Fee (Green Levy)	
	CAD_{2008}	EUR_{2008}[a]	CAD_{2008}	EUR_{2008}[a]
Passenger cars				
≤5.5	$ 2,000	€ 1,283	$ 0	$ 0
>5.5-6.0	$ 1,500	€ 962	$ 0	$ 0
>6.0-6.5	$ 1,000	€ 641	$ 0	$ 0
>6.5-<13	$ 0	€ 0	$ 0	$ 0
13-<14	$ 0	€ 0	$ 1,000	€ 641
14-<15	$ 0	€ 0	$ 2,000	€ 1,283
15-<16	$ 0	€ 0	$ 3,000	€ 1,924
≥16	$ 0	€ 0	$ 4,000	€ 2,564
Light trucks[b]				
>6.8-7.3	$ 2,000	€ 1,283	n/a	n/a
>7.3-7.8	$ 1,500	€ 962	n/a	n/a
>7.8-8.3l	$ 1,000	€ 641	n/a	n/a

[a]   Average exchange rate in 2008 CAD/EUR 1.5594 (Eurostat, 2013).
[b]   Includes SUVs, vans, and other light trucks.
Source: Human Resources and Skills Development Canada, 2011 for rebates; CRA, 2007 for fees.

Figure 26 evidences the (uneven) step-based feebate function for passenger cars; the slope of the feebate ranged from 5.5 l/100 km to 16 l/km. Passenger cars consuming more than 6.5 but less than 13 l/100 km are not levied any fees, nor can they apply for a rebate; there will not be an incentive to improve the fuel consumption of these vehicles therefore, except for those vehicles close to the rebate pivot point. For other performance levels, only vehicles close to the step-functions will be improved.

The rebate-only system for light trucks had an even step-based function on the other hand (uniform performance and rebate steps); for each 0,5 l/100 km improvement in fuel-efficiency the rebate was increased by $ 500.

Figure 26   Canadian feebate system for passenger cars
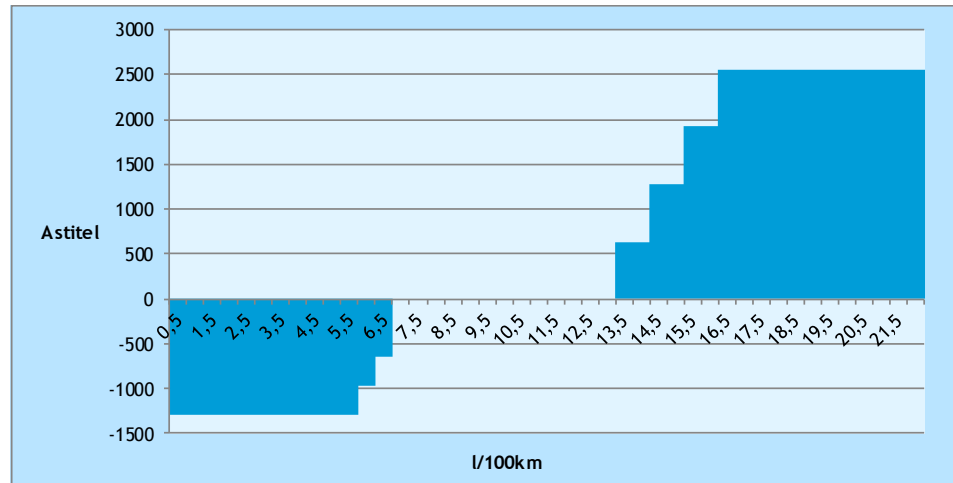
The ICCT (2012) estimated the slope of the Canadian fee to be
- € 20.1 per g/km. No studies could be found that estimate the effectiveness
of the programs. However, according to the ICCT (2010) the feebate only
applied to 15 passenger car models; the effect is therefore likely to have been
small.

B.4   Irish CO_2-differentiated vehicle registration and motor tax

Ireland has differentiated both it's vehicle purchase (vehicle registration) tax
and its annual ownership (motor) tax on a CO_2 basis since 2008. As is shown in
Table 9, both tax rates increase with the CO_2 emission category of the vehicle.
The Irish taxes can therefore be considered a fee-only program with a
(uneven) step-based fee function. The system has been operationalised with a
g/km metric.

The ICCT (2010) estimated the slope of the purchase tax (in € per g/km), and
concluded that the slope of the Irish fee-only system on purchase taxes is
almost five times higher than the French feebate system on new vehicle
purchases (-86.4 € per g/km vs. -18.1 € per g/km, respectively). It should be
mentioned though that the French feebate slope covers a slightly wider range
of CO_2 emissions than the Irish purchase tax (60–250 g/km vs. 80–225 g/km).
The slope of the ownership tax has a wider vehicle coverage of 0–225 g/km.

Table 9   Irish CO_2-differentiated vehicle purchase and ownership tax structure in 2013

CO_2 emissions in g/km	Vehicle purchase tax[a] in % of the vehicle's open market selling price	Annual vehicle ownership tax[a] in € per year
0	14%	120
>0-≤80	14%	170
>80-≤100	15%	180
>100-≤110	16%	190
>110-≤120	17%	200
>120-≤130	18%	270
>130-≤140	19%	280
>140-≤155	23%	390
>155-≤170	27%	570
>170-≤190	30%	750
>190-≤225	34%	1,200
>225	36%	2,350

[a]   Official name of the purchase tax: 'Vehicle Registration Tax (VRT)'.
      Official name of the ownership tax: 'Motor tax'.

Source: VRT tax rates from VRT (2013) and motor tax rates from the Department of Environment, Community, and Local Government (2013).

No ex-post evaluations on the effectiveness of the Irish fee-only system could be found.

Giblin & McNabola (2009) also estimated a switch of 6% to diesel cars, but this seems an underestimation as recent sales data shows that the share of diesel cars has more than doubled; from 25 to 57% (CSO, 2010). It is unclear to what extent the tax reform has contributed to this increase, but it is likely that this increase is at least partially caused by consumers switching to more-efficient diesel cars to obtain a lower tax rate.

B.5   United States' Gas-Guzzler Tax

In 1980, the US implemented the Gas-Guzzler tax, which levies a purchase tax on vehicles with a fuel economy below 22.5 mpg (Miles Per Gallon) (EPA, 2012). Table 10 shows that the fees increase with decreasing fuel economy and are defined per fuel economy category; it can therefore be seen as a fee-only program with a step-based fee function that is based on a mpg metric.
The performance classes are defined in equal steps, but the fees are not; the step-based function can therefore be considered as uneven. The fee slope covers vehicles with a fuel economy between 22.5 to 12.5 mpg and is estimated to be - € 18.3 per g/km for these vehicles on average (ICCT, 2010).

Table 10   US Gas Guzzler Tax system

Fuel economy in miles per gallon (mpg)	Tax (fee) in $	Estimated tax in €[a]
≥22.5 mpg	0	0
21.5-<22.5 mpg	1,000	754
20.5-<21.5 mpg	1,300	980
19.5-<20.5 mpg	1,700	1,282
18.5-<19.5 mpg	2,100	1,583
17.5-<18.5 mpg	2,600	1,960
16.5-<17.5 mpg	3,000	2,262
15.5-<16.5 mpg	3,700	2,790
14.5-<15.5 mpg	4,500	3,393
13.5-<14.5 mpg	5,400	4,072
12.5-<13.5 mpg	6,400	4,826
<12.5	7,700	5,806

[a] Estimated with a USD/EUR exchange rate of 0.754 (exchange rate of August 6th 2013).
Source: EPA, 2012.

The fee-only system discourages the most inefficient vehicles, but does not provide any incentives to improve the fuel economy of vehicles beyond the 22.5 mpg pivot point. According to Greene et al. (2005) the Guzzler tax is less effective than a comparable feebate system (in terms of improving fuel-efficiency) as it only covers a small share of the market. This is in line with estimates from the ICCT (2010); according to them, only 0.3 to 2.6% of the passenger car sales are subject to the tax. These are mostly larger, luxurious cars, with high vehicle sales prices for which the tax is only a small share of the total price. Inefficient vehicles that were close to the pivot point were redesigned to fall slightly above the threshold of 22.5 mpg, the ICCT (2010) argues.

No other studies on the effectiveness of the US gas-guzzler tax were found.

B.6   German CO_2-based annual vehicle registration tax

In 2009, Germany has revised its annual vehicle registration (i.e. ownership) taxes (VRT) and included a CO_2-based component in addition to an engine displacement component (€/100 cubic centimetres (cc)). The tax is therefore operationalized with two metrics; the engine's cc (differentiated by two engine types) and gCO_2/km. The CO_2-based component is set at € 2/gCO_2 for each gram above 120 g/km (ICCT, 2010). No rebates are given to vehicles below 120 g/CO_2. The German VRT tax can therefore be considered as a fee-only system. When only looking at the CO_2-based component, the fee pivot point is 120 gCO_2/km, with a zero slope range at the left side of this pivot point and a linear feebate function at the right side. The German fee-only system gives no incentives to reduce emissions beyond the 120 gCO_2/km fee pivot point. However, the linear aspect for the remainder of the vehicles ensures that an incentive for continuous improvement is provided.

When taking both factors into account (i.e. the combined fee for engine displacement and CO_2), the slope of the German fee-only system is - € 2.3 per g/km (gasoline) to - € 3.2 per g/km (diesel). Although this is a lot flatter than the other feebate(-like) systems, it should be kept in mind that this is an annual tax, while most other fee systems only levy taxes at the point of purchase; hence over the lifetime of the car the incentive provided by this

measure may be close to the incentives provided by purchase related feebate schemes.

Figure 27 CO_2-based part of the German annual VRT
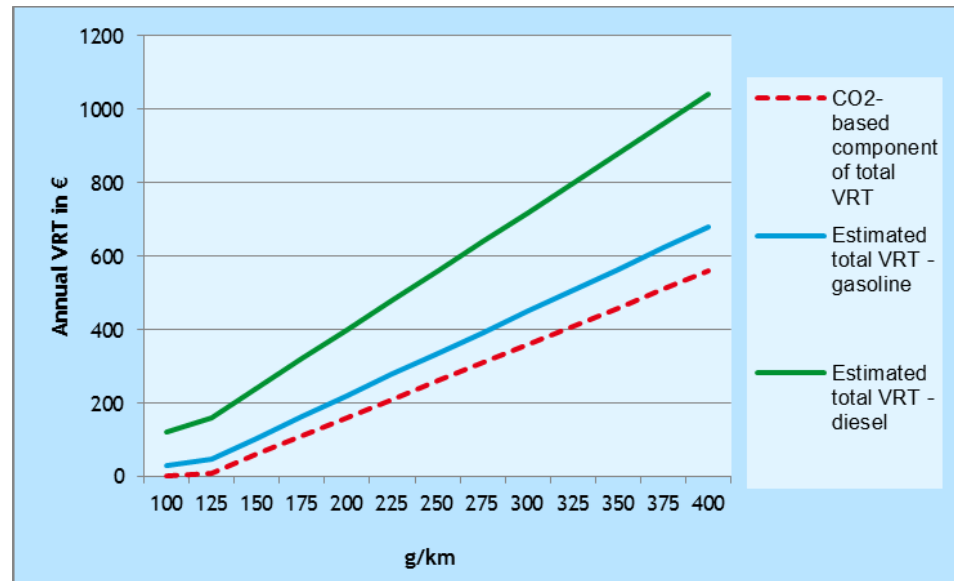
Source: ICCT, 2010, adjusted by CE Delft.

Klier & Linn (2012) have evaluated the short-run effects from the German tax reform. According to them, the CO_2-differentiated annual registration tax resulted in a reduction of 1.67 g/km between the first and second half of 2009, which is approximately a 1.1% reduction in the average emission factor of newly sold cars.

B.7   Swedish CO_2-differentiated annual vehicle circulation tax

In 2006, Sweden redesigned its annual vehicle circulation (ownership) tax and directly related the tax rate to CO_2 emissions (Klier & Linn, 2012). The basic tax rate for petrol, diesel and LPG cars has been set at € 42[2] and an additional € 2.30[2] is charged for each gram of CO_2 that is emitted above 117 g/km (ACEA, 2013). For diesel cars the resulting tax amount is multiplied by 2.33 and these vehicles pay an additional € 29-58[2] (depending on the date of registration; after or before 2008) (ibid.). Hence, diesel vehicles are charged more than a gasoline vehicle with the same emissions. Vehicles powered by alternative fuels (ethanol, gas) pay a lower CO_2-based amount of € 1.16[2] per g/km emitted above 117 g/km (ibid.), and therefore are charged less than comparable gasoline vehicles. Figure 28 summarises the system graphically.

The Swedish fee-only system can be viewed as an attribute-based system that adjusts fees with the fuel type of the vehicle. The feebate function is linear with a zero-slope element for vehicles with emissions below the fee pivot point (117 gCO_2/km). This implies that no incentives are given to improve vehicles that emit 117 gCO_2/km or less.

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2   Annual exchange rate of 2013: EUR/SEK = 8.6066 (Eurostat, 2013).

Figure 28 Swedish annual circulation tax in 2013
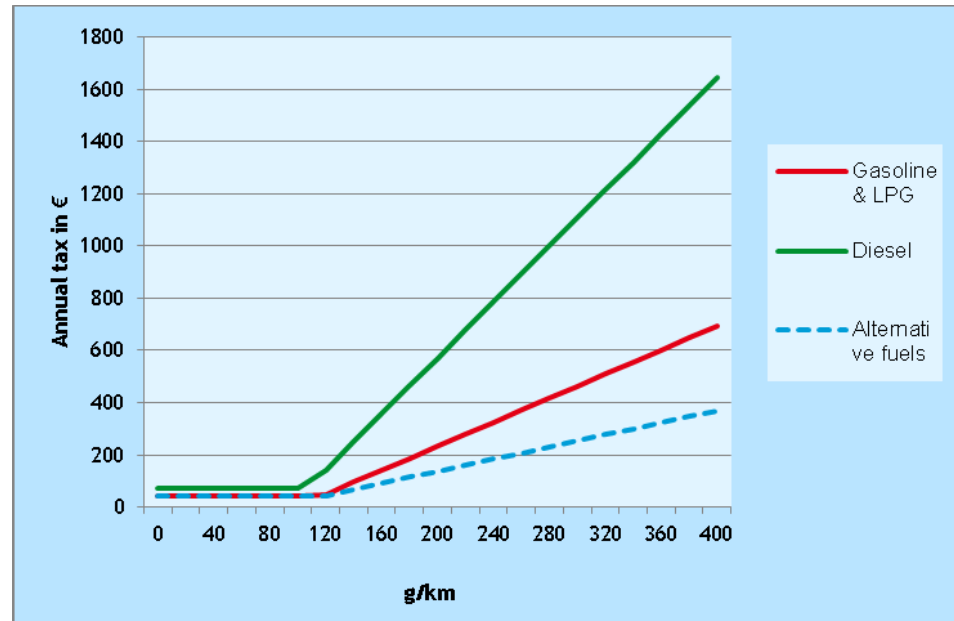
From 2007 to 2009, a 'green car rebate' of € 1,162[2] was granted to vehicles that met the national green car definition. These were mostly vehicles which consumed E85 or biogas and highly energy-efficient vehicles emitting less than 120 g/km (Naturvardsverket, 2013). From 2009 onwards, the green car rebate was replaced by a five-year exemption of vehicle taxes (Naturvardsverket, 2013).

Klier & Linn (2012) compared the effects of the CO_2-based vehicle taxes of France, Germany and Sweden, and concluded that the impact of the Swedish tax is lowest as compared to these other countries. The observed average CO_2 emission rates decreased with 1.54 g/km (from 188.5 g/km in the first three quarters of 2006 to 187 g/km in 2007), but only 0.57 g/km (37%) is attributable to the CO_2-differentiated annual vehicle registration tax. This implies that the tax resulted in a reduction in average emission factors of new registrations of 0.3%.

B.8 UK's CO_2-differentiated vehicle excise duty

The government of the UK revised the annual vehicle excise duty (ownership tax) and differentiated the tax rate with thirteen emission classes (ACEA, 2013). The rates are slightly higher in the first year the vehicle is registered than in the years hereafter, and vehicles with alternative fuels receive a small discount. The taxes are summarised in Table 11.

The tax system in the UK can be compared to a fee-only program with a (uneven) step-based fee function, both in terms of the performance class steps as well as in terms of the uneven fee amounts. The attribute used to adjust the feebate amount is 'fuel type'.

Table 11   Vehicle registration tax structure in the UK

Band	CO_2 emissions in g/km	Diesel and petrol cars		Alternative fuel cars	
		First year rate in €[a]	Registered vehicles yearly rate in €[a]	First year rate in €[a]	Registered vehicles yearly rate in €[a]
A	≤100	0	0	0	0
B	101-110	0	23	0	12
C	111-120	0	35	0	23
D	121-130	0	123	0	112
E	131-140	147	147	135	135
F	141-150	164	164	153	153
G	151-165	206	206	194	194
H	166-175	335	235	323	223
I	176-185	393	258	382	247
J	186-200	558	305	546	294
K	201-225	728	329	716	317
L	226-255	986	558	975	546
M	>255	1,251	575	1,239	564

[a] Estimated with average exchange rate in 2013: GBP/EUR= 0.8515 (Eurostat, 2013).
Source: Government UK, 2013.

The average CO_2 emissions of the new UK car fleet have decreased from 173 g/km in 2003 to 144 g/km in 2010 (Corpus, 2011). It is unclear how much of this effect is caused by the differentiated vehicle registration tax.

B.9   Overview of different country designs

As became evident in the previous subsections, the feebate(-like) system designs differ significantly between countries, which is summarised in Table 12.

Table 12   Overview of feebate(-like) systems on vehicle purchases and ownership in different countries

	Type of system	Feebate metric	Attribute adjustment	Feebate function	Vehicle coverage of the feebate	Estimated effectiveness
France	Feebate on purchase tax	gCO_2/km	None	(uneven) Step-based: 10 categories	60 to 250 g/km	5-6% reduction in emission factor new vehicles
Netherlands	Feebate on purchase tax	Energy label	None, but implicit attribute = Vehicle size	(uneven) Step-based: 7 categories	20% more fuel-efficient to 30% less fuel-efficient than other vehicles in size category	0.2-1% reduction in emission factor new vehicles
Canada	Feebate on purchase tax	l/100 km	Rebate: vehicle type (2 categories) Fee: none	(uneven) Step-based: passenger cars 8 categories, light trucks 3 categories	Passenger cars: 5.5-16 l/100 km, light trucks: 6.8-8.3 l/100 km	Unknown, but small vehicle coverage
Ireland	Fee-only on purchase and ownership tax	gCO_2/km	None	(uneven) Step-based: purchase fee 11 categories, ownership 12 categories	Purchase: 80-225 g//km Ownership: 0-225 g/km	Unknown. Switch to diesel cars
US	Fee-only system on purchase tax	Mpg	None	(uneven) Step-based: 12 categories	22.5-12.5 mpg	Unknown, but small vehicle coverage
Germany	Fee-only system on ownership tax	2 metrics: cc and gCO_2/km	Engine type: 2 categories (for the cc metric)	Linear fee function with zero-slope element	CO_2-based metric: 120 g/km or more	1.1% reduction in emission factor new vehicles
Sweden	Fee-only system on ownership tax	gCO_2/km	Fuel type: 3 categories	Linear fee function with zero-slope element	117 g/km or more	0.3% reduction in emission factor new vehicles
UK	Fee-only system on ownership tax	gCO_2/km	Fuel type: 2 categories	(uneven) step-based fee function: 13 categories	100-255 g/km	Unknown

As evidenced in Table 12, the implemented feebate(-like) schemes differ significantly between countries. Two general remarks can be made though. Firstly, most countries have operationalised their scheme with a CO_2-based metric. Secondly, the majority of the countries have implemented an uneven step-based feebate function. It is unclear why these countries have chosen an uneven step-based function instead of a step-based function with uniform step sizes or a linear feebate function.

Additional examples of feebate and feebate-like systems can be found in the GFEI Cleaner, More Efficient vehicles tool:

http://www.unep.org/transport/gfei/autotool/ and

http://www.unep.org/transport/gfei/autotool/approaches/economic_instruments/fee_bate.asp

Annex C Design options feebate systems

C.1 Introduction

In addition to the basic feebate concept that was outlined in Annex A, several feebate design options can be chosen by the user. These decisions are made in the tab 'Feebate Design'. This annex will describe for each design option the following aspects:

− the location of the design option in the tool (i.e. where can the option be chosen/adapted);
− the default option in the tool:
  • short description of (default) option;
  • advantages and disadvantages of the default option;
  • countries that have implemented this option in their feebate (-like) scheme.
− other options that can be chosen in the tool:
  • short description of option (if necessary);
  • advantages and disadvantages of each option;
  • countries that have implemented this option in their feebate (-like) scheme.
− other design options that have not been included in the tool.

The remainder of this annex describes these aspects for the feebate metric/unit (Section C.2), the feebate rate (Section C.3), the rebate function (Section C.4) the feebate pivot point (Section C.5), attribute adjustments (Section C.6), point of administration (Section C.7) and pivot point adjustment (Section C.8).

C.2 Feebate metric/unit

> **Tab in the tool:** 'Feebate Design'
> **Location within tab:** 'Metrics' and 'Units' are located in the upper right corner.
> **Instruction for using the tool:** Select the desired metric and unit from the drop-down menus. Once chosen, click on the 'Update' button to align the rest of the feebate design tab with the choices made.

Different metrics can be chosen to operationalise the feebates.
The default value chosen for the tool is **'gram CO_2 per kilometre' (gCO_2/km).**
The main advantage of using a CO_2-based metric is that it is fuel-neutral; it automatically takes into account any differences in the CO_2 emissions of different transport fuels. This may be particularly important when vehicles with alternative fuels (e.g. high biofuel blends (E85) or compressed natural gas (CNG)) and with alternative drivelines (e.g. plug-in hybrids and electric vehicles) obtain higher market shares, as the CO_2 emissions of these vehicles deviate more significantly from vehicles with conventional fuels. A E85 vehicle for example, may have the same fuel consumption performance (in l/km) as a regular petrol car, but will have significantly lower CO_2 emissions. A metric based on CO_2 emissions takes such differences into account automatically.

Another advantage of this metric is that it provides a similar financial incentive to improve the fuel-efficiency with one gCO_2 over the whole range of vehicles[3]. This is desirable from an environmental point of view, as it should not matter whether a relatively efficient or inefficient car is further improved (i.e. it should not matter where the improvement takes place).

A gCO_2/km metric has been implemented in the feebate(-like) schemes of France, Sweden, Ireland, UK, and Germany. A more detailed description of these schemes can be found in Annex B.

The user can also choose for one of two fuel-based metrics: **'litre/100 kilometres' (l/100 km)** or **'kilometres per litre' (km/l)**. Both these metrics do not take differences in the CO_2 content of different transport fuels into account. Hence, two vehicles with the same fuel consumption could receive the same fee or rebate even though their CO_2 emissions can be different.

An advantage of the l/100 km metric is that it also – like the gCO_2/km metric - provides a similar financial incentive to improve the fuel-efficiency over the whole range of vehicles. The km/l metric on the other hand does not; it provides a larger financial incentive to improve vehicles that are already efficient, while the incentive to improve inefficient vehicles is lower. The km/l of an efficient car are higher than for an inefficient car, hence, improving the km/l of an efficient car is a smaller improvement in relative terms than for an inefficient car. However, if both receive a fixed € per km/l amount, the incentive (in l/100 km) to improve the fuel-efficiency of the car[4] is larger for the efficient car than for the inefficient one[5]. This is undesirable from an environmental point of view, as it should not matter whether a relatively efficient or inefficient car is further improved (i.e. it should not matter where the improvement takes place).

A l/100 km metric has been used to operationalise the Canadian feebate scheme, which can be found in Annex B.3. The US feebate-like scheme has implemented a mi/gal metric, which is comparable to the km/l metric and is further described in Annex B.5.

The three metrics outlined above, can be converted to miles and gallons instead of kilometres and litres (i.e. gCO_2/mi, gal/100 mi, and mi/gal (mpg)) in the 'Units' section of the 'Feebate Design Tab'. The miles and gallon variants have the same advantages and disadvantages of the metrics described earlier in this section.

Irrespectively of which feebate metrics is chosen, it is necessary to decide whether to base the metric on test or real-world data. While the former mentioned data has mostly practical advantages in terms of the feasibility of

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[3] The same fee/rebate is given for a 1 gram CO_2 improvement for a relatively fuel-efficient car (e.g. from 110 g/km to 109 g/km) as for a relatively fuel-inefficient car (e.g. from 250 g/km to 249 g/km).

[4] Notice that a financial incentive in terms of l/100 km is – in contrast to a financial incentive in terms of km/l - directly related to the fuel-efficiency of the car.

[5] For example, assume a fuel-efficient car which drives 25 kilometres per litre and a fuel-inefficient car which drives 10 kilometres per litre. Improving the kilometres per litre with one kilometre results in a relative improvement for the fuel-efficient car of 4%, while the relative improvement for the fuel-efficient car is equal to 10%. If the fee/rebate is defined in terms of km/l and is set at € 20 per km/l, the financial incentive provided to the fuel-efficient car is equal to € 500 per l/km, while for the fuel-inefficient car the financial incentive is just € 200 per l/km.

the performance measurement, the latter mentioned one has advantages in terms of measuring 'real' performance of the vehicles. Many studies have shown that actual, real-world fuel consumption and emissions figures deviate significantly from the test results (e.g. the ICCT (2013) found an average deviation of 25%). Thereby, studies indicate that the deviation will differ between different fuel consumption levels; the more efficient the vehicle is in test-cycles, the higher the relative deviation will be with real-world emissions (TNO, forthcoming). For feebates, this implies that if the feebate is based on test-cycles, it may occur that a particular rebate amount is given to a vehicle that is higher than if the rebate was determined with real-word emissions. However, measuring real-world fuel consumption or CO_2 emissions at the vehicle level has not been operationalised yet and would require new and expensive monitoring systems (CE Delft & SQ Consult, 2014). Therefore, it would be more feasible to base the metric on test-emissions.

Box 3	Feebate metrics that have not been included in the tool

> There is one feebate metric that is not included in the tool: the relative **'energy label'** is not a very commonly used metric, but has been implemented in the Netherlands from 2006-2010 (see Annex B.2). This Dutch energy label is an indication of the relative energy-efficiency of a vehicle in its own size class, and therefore makes implicit use of the attribute 'vehicle size' (attribute-based systems are described in more detail in Section C.6). This metric has the disadvantage of assigning the same feebate amount to vehicles with completely different CO_2 or fuel-efficiency performance levels. However, as consumers are likely to buy a new vehicle within one size class (Peters et al., 2008), it is possible to give a (stronger) price signal within the range of options that a consumer considers for purchase. Obviously, using the relative energy label as pivot point requires that a label system is implemented firstly, which may often not be the case in developing countries; this is the main reason for not including this design option in the tool.

C.3 Feebate rate (amount)

> **Tab in the tool:** 'Feebate Design'
> **Location within tab:** 'Feebate Function Shape Control' (bottom half of tab) in table row 'Rate USD per…' for sloped sections and in table row 'Rebate/fee value' for flat sections.
> **Instruction for using the tool:** Click on a section's rate, overwrite it with a new value

The feebate rate (in USD per metric)/amount (total feebate amount in USD) determines the efficiency improvements that will result from the feebate system as it directly influences the strength of the price signal that is given to manufacturers/consumers. Obviously, the higher the feebate rate/amount, the steeper the slope of the feebate function, and hence, the higher the incentive will be for manufacturers to improve the fuel-efficiency of a car and/or for consumers to buy a more fuel-efficient car. This implies that the higher the feebate rate/amount, the more effective the system will be in improving the fuel-efficiency and in reducing the CO_2 emissions of the vehicle fleet. Although a higher feebate rate/amount will result in a higher overall effectiveness of the system, rates that are too high may result in public opposition and in equity concerns. Setting the feebate rate/amount will therefore be a trade-off between the system's effectiveness and in obtaining public support.

The user can choose any value as feebate rate/amount by overwriting existing values. For linear rebate functions with sloped sections (see Section C.4), the user has to enter an USD amount for the respective metric (e.g. USD per gCO_2/km). For step-based functions with flat sections (see next section), the user has to insert a total amount in USD for each performance class (i.e. for each step/section).

The default feebate rate/amount has been determined by looking at existing feebate rates. Implemented feebate rates range from 20 to 30 euro per gCO_2/km. The user can determine the feebate rate by looking at the feebate rates of already implemented feebate systems or by looking at the investment costs/CO_2 saving of the most important CO_2 reduction measures for example.

C.4   Rebate function

Tab in the tool: 'Feebate Design'
Location within tab: 'Feebate Function Shape Control' (bottom half of tab) in table row 'shape examples'.
Instruction for using the tool: Select a feebate function shape from the drop-down menu as a basis. Hereafter, you can customise the function:
-   Determine the performance range of each section by overwriting the values in the row 'how many sections?'
-   Determine the amount of the feebate by overwriting the values in 'Rebate/fee value' (flat sections) or 'Rate in USD per..' (sloped sections)

If you also want to change the number of sections or the shape of individual sections (flat/ sloped), you need to select the option 'Design your own' in the drop-down menu of 'Shape examples'.

The default design of the rebate function (i.e. shape of the function: see red line in Figure 29) is set to be a **'linear rebate function'**. The main advantage of this design (shown in Figure 29) over other designs (e.g. step-based rebate functions) is that the fee/rebate is directly related to the performance of the vehicle (e.g. in € per gCO_2/km or in € per l/100 km). The linearity of the rebate function implies that two vehicles with a different performance will never receive the same feebate amount, not even if their fuel consumption only differs slightly (ICCT, 2010). Consequently, a continuous incentive is given to manufacturers to improve their vehicles (likewise, it will provide a continuous incentive to consumers to buy more fuel-efficient cars), as reducing fuel consumption/CO_2 emissions will always result in a lower fee or in a higher rebate (ICCT, 2010).

There are no country examples with a pure linear rebate function. However, the function in the Swedish feebate-like system is linear from 117 gCO_2/km onwards and the CO_2 component of the German feebate-like system is linear from 120 gCO_2/km. A more detailed description of these schemes can be found in Annex B.

Figure 29   Feebate system with a linear rebate function
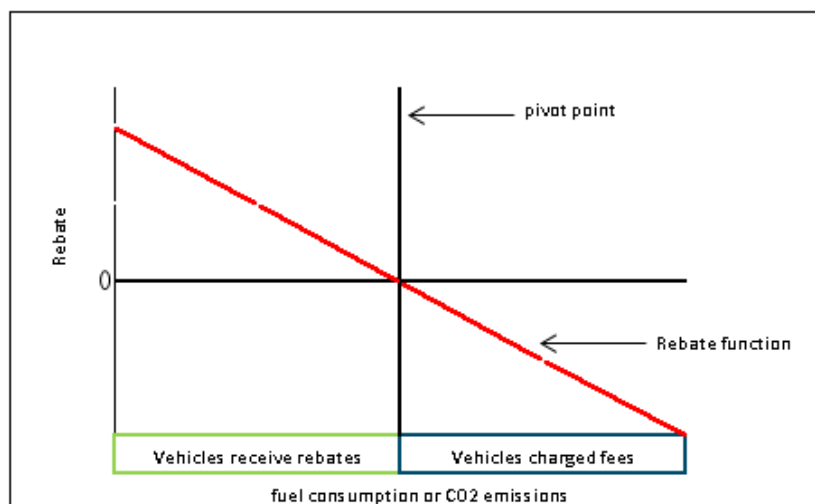
Source: ICCT, 2010, adjusted by CE Delft.

Several other design options are included in the tool. Closely related to the design shown in Figure 3 is the **'linear piecewise rebate function'.** With this design, the slope of the rebate function is still linear, but different feebate rates are set for different vehicle performances (see Figure 30). This still provides the continuous incentive to improve, but the strength of the incentive can be differentiated for different performances. This may be desirable from a social point of view (e.g. by increasing the burden on consumers of large, inefficient, luxurious cars). However, from an environmental point of view this should not matter (i.e. for tackling climate change, improving an inefficient car with 1g/km is just as valuable as improving a car that is already relatively efficient with 1 g/km).

None of the country systems described in Annex B have implemented a linear piecewise rebate function.

Figure 30   Feebate system with an linear piecewise rebate function
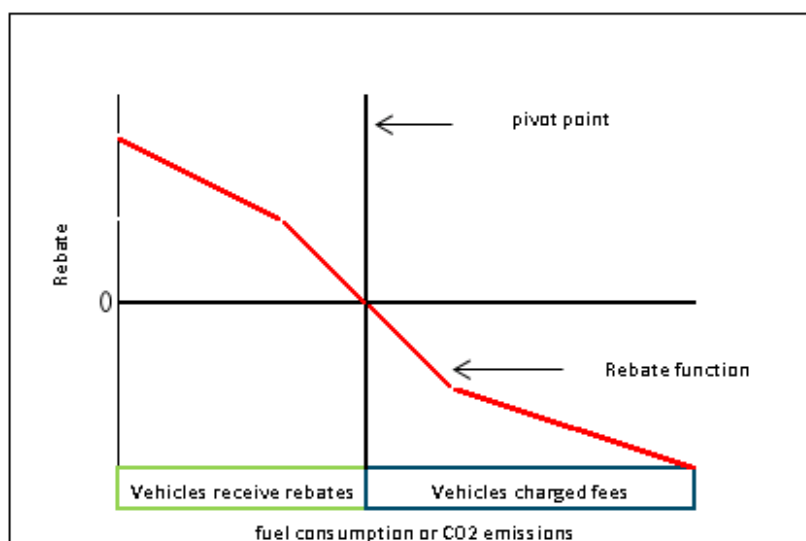
Another option for which the user can choose is a **'step-based function with uniform steps'**, which is shown graphically in Figure 31. With a step-based feebate rate, the same feebate is given to a range of vehicle performances (i.e. differentiated categories of CO_2 emissions, fuel consumption, etc.) and the feebate rate increases with uniform steps. A disadvantage of this design (in contrast to the linear functions) is that the incentive for continuous improvement will be lower. Manufacturers (and consumers) will mainly have an incentive to improve those vehicles that are close to a step, as only then will their rebate or fee be increased or reduced (ICCT, 2010). I.e. it is likely that manufacturers will only adopt minimal measures to reach the next level, and not improve the vehicle's performance further hereafter, as this will not result in higher rebates or lower fees. However, with a step-based system with uniform step sizes, the system does provide equal incentives over the whole range of vehicle performances (see the blue-dotted line in Figure 31).

Figure 31   Feebate system with a step-based rebate function with uniform steps
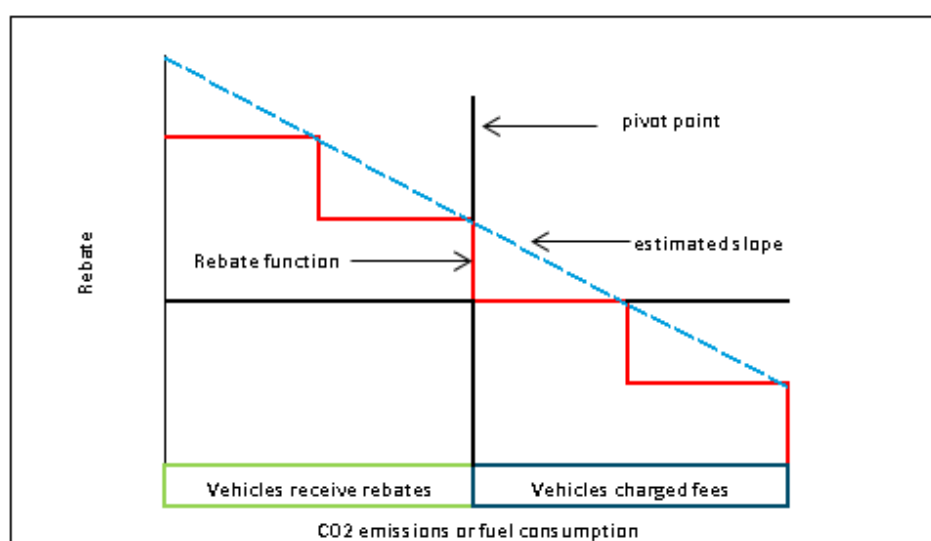
Source: ICCT, 2010, adjusted by CE Delft.

None of the country systems described in Annex B have implemented a step-based function with uniform step sizes.

The user can also choose for a **'step-based system with uneven steps'**. As was the case for a step-based system with uniform steps, this rebate function provides the same feebate to a range of vehicle performances, however, the feebate rate is different for different performance classes. This design is shown in Figure 32. A step-based system with uneven steps mainly provides an incentive to manufacturers to improve those vehicles close to a step (i.e. low incentive for continuous improvement). However, with this design the incentives for improvements will be larger for some performance categories than for others, as the inequality of the feebate rate results in different feebate slopes (see the blue-dotted line in Figure 32). In the example provided below, it will pay-off relatively more to improve vehicles left of the pivot point than improving those on the right, as the resulting slope from the rebate function is steeper.

Uneven step functions can be used to realise a relatively stronger price incentive to improve the performance of particular vehicle classes (e.g. the most polluting vehicles); hence, choosing an uneven step function can be a political consideration. In this case, the most inefficient cars, which are often the more expensive cars, could have to pay relatively more for the efficiency improvement than the more efficient, smaller cars (i.e. the opposite situation as the one shown in Figure 33). From an equity point of view this may be perceived as a fair system, as it will place the largest burden on those with the highest incomes[6]. However, from an environmental point of view, it does not matter where the efficiency improvement is realised.

A wide variety of countries have already implemented a feebate(-like) system with a step-based rebate function with uneven steps, including France, the Netherlands, Canada, Ireland, the US, and the UK. A more detailed description of these schemes can be found in Annex B.

Figure 32   Feebate system with a step-based rebate function (uneven step sizes)
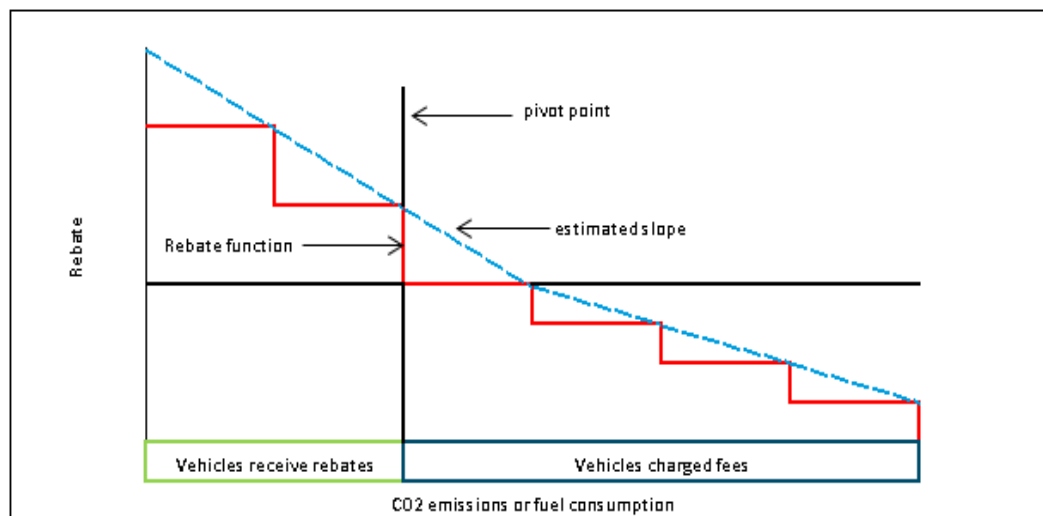
In addition to the four main categories of rebate function designs, the user can choose for the option to **'design your own'** rebate function. In this case the user can, for example, choose to combine linear with step-based designs, or to design linear rebate functions with zero-slope elements. This latter-mentioned design option is shown graphically in Figure 33. The chosen combinations will have comparable advantages and disadvantages as the respective designs described above. As can be seen in Figure 33 for example, the slope of the feebate rate is still linear for a significant performance range, which provides a continuous incentive to improve those vehicles. However, it also has flat (i.e. zero slope) elements for a particular range of vehicle performances. Within this range, vehicles with different levels of fuel consumption/CO_2 emissions receive the same rebate/fee (note that in this example the zero slope range implies that these vehicles receive no fee nor a rebate). Consequently, the incentive to improve the fuel-efficiency of these vehicles is lowered. Hence, within this range, there is mostly an incentive to improve the

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[6]   Note that this could also be obtained by implementing an uneven (non-)continuous feebate function, by implementing an even step-based function with an attribute adjustment (further described later in this section) or by implementing multiple feebate functions (i.e. a separate feebate function for each vehicle class).

performance of those vehicles that are close to the rebate pivot point (ICCT, 2010). Such a design may be chosen to obtain a higher level of social acceptance by only rewarding the most efficient vehicles a rebate and by only punishing the most inefficient ones with a fee.

Figure 33   Design your own rebate function (example of a linear function with zero-slope elements)
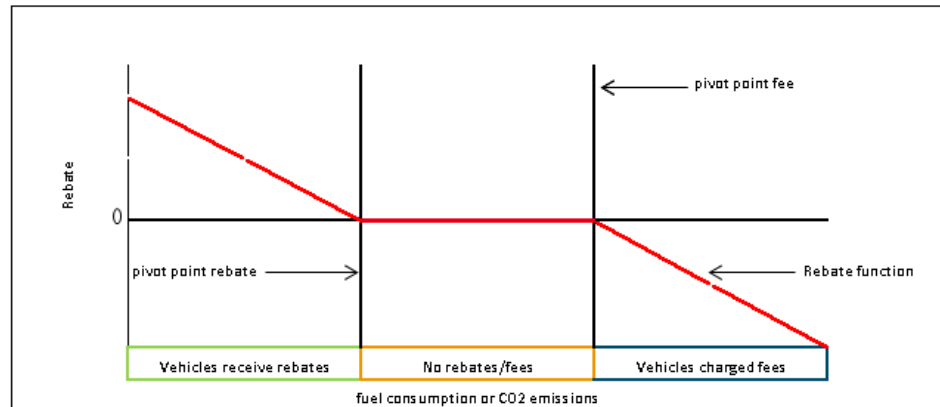
Source: ICCT, 2010, adjusted by CE Delft.

Both the feebate-like systems of Sweden and Germany (the CO_2-based component of the system) combine a linear rebate function with zero-slope elements. More details on these schemes can be found in Annex B.7 and B.6, respectively.

As a result of this last-mentioned rebate function design option, all possible design options that can be thought of are included in the tool.

C.5   Feebate pivot point

> **Tab in the tool:** 'Feebate Design'
> **Location within tab:** 'Pivot point control' (upper middle square of tab)
> **Instruction for using the tool:**
> If you want the tool to calculate the pivot point for you, choose for one of the two annual adjustment options from the drop-down menu. After selecting this option you can select a pivot point that results in a revenue neutral system or a net revenue to the government from the second drop-down menu.
>
> If you want to choose a pivot point value yourself, select manual pivot point control or lagged adjustment based on trigger from the first dropdown menu in the pivot point control panel.

The feebate pivot point determines the cost-revenue distribution between the government and the market. For the two annual adjustment options, the default pivot point is set to generate a '**revenue-neutral scheme**'. I.e. the pivot point is set at a point where rebates and fees are in balance: the fees received are used to pay the rebates. Both the government and the market have a net total system cost of zero therefore. If the pivot point is adjusted regularly (e.g. annually) to take into account improvements in fuel-efficiency (further elaborated on in Section C.8), this results in a sustainable, self-supporting system.

The French and Dutch feebate systems were designed to be revenue-neutral. The Canadian system is a pure feebate system (i.e. charge both fees and provide rebates) as well, but it is unclear whether it was designed as a revenue-neutral system. A more detailed description of these three schemes can be found in Annex B.

The user can also choose for a pivot point that results in a '**net revenue to the government**' when one of the annual adjustment options was chosen. With this feebate design, more fees are levied than rebates given, which may be an attractive alternative for developing and transition countries, as these governmental budgets are usually limited. The revenue can then be used as a buffer for unexpected shortfalls of the feebate system.

It is unclear if there are any feebate systems that aimed to generate a net-revenue to the government (possibly the Canadian system). However, there are several feebate-like (i.e. fee-only) system that generate a net revenue to the government for sure, these include: Ireland, US, Germany, Sweden, and the UK. Annex B provides more information on these schemes.

With the other two adjustment options (manual pivot point control or lagged adjustment based on trigger), the user can adjust the pivot point manually. Hence, the cost-revenue distribution is dependent on what the user chooses. The user can estimate the appropriate pivot point with several information sources, for example with the average fuel consumption or CO_2 levels of the current vehicle fleet (incl. improvements that have been obtained over the years). Another option may be to use existing fuel consumption/CO_2 standards, as these standards provide an indication of which fuel-efficiency improvements are likely to be obtained in the coming years. In most developing countries, this latter-mentioned information source will be unavailable; however, the strictness of the standards set in other countries may provide relevant information as well, and thereby, these countries import a lot of their vehicles from countries that do have such standards.

Irrespectively of the cost-revenue distribution or pivot point that is chosen, a mechanism to cope with (unexpected) shortfalls and over-payments is needed. This can for example be established by appointing a banker, which can be the government or an organisation, to temporarily lend the system money in case shortfalls occur and to temporarily store money in case of over-payments (ICCT, 2010). As developing countries usually not have sufficient resources available to deal with shortfalls in their revenue streams, setting up such back-up mechanisms is very important. It is unclear what the administrative costs are of doing so. The costs of setting up back-up mechanisms are therefore not included in the tool. A costless back-up mechanism to cope with the risk of shortfalls is to set the estimated appropriate pivot point for obtaining the desired cost-revenue distribution a little more to the left.
This will result in levying slightly more fees than would otherwise be the case. Especially in the first years of operation, this may be a good way to gather back-up sources for future unexpected imbalances. Thereby, the risk and amount of unexpected shortfalls will be lower.

Ideally, the pivot point that is set when implementing the feebate will have to be adjusted as the vehicle fleet will become more efficient, which in turn will change the cost-revenue distribution. This will be further described in Section C.8.

Box 4   **Pivot point options not included in the tool**

> There is one other option for setting the pivot point. In theory, the pivot point could be set at a level to result in a **net revenue to the market** (i.e. manufacturers/consumers). In this case, the amount of rebates granted is higher than the amount of fees charged. With this pivot point the feebate system can be considered as a subsidy and it will result in shortfalls in the governmental budget. As this requires sufficient resources, it is unlikely to be an attractive option for most developing and transition countries. Therefore, it has not been included in the tool.

C.6   Attribute adjustments

> **Tab in the tool:** 'Feebate Design' – 'Advanced Design options' button
> **Location within tab:** 'Attribute Adjustment' button
> **Instruction for using the tool**: enable the desired attribute adjustment by selecting 'enabled' in the respective drop-down menu. The user can also adjust the default value for the flat rate factor (explained below) by overwriting this default value.

The feebate system can be designed with or without adjusting the fees and rebates to particular attributes (i.e. vehicle characteristics, such as vehicle size, vehicle weight, etc.) (ICCT, 2010). A feebate system with 'no attributes' is set as the default option. In this case, the fee or rebate amount is determined solely by the vehicle's performance (Peters et al., 2008) in terms of the defined metric and no corrections are applied. This is shown graphically in Figure 34 for a feebate system with a linear feebate function. The rebate for a car with 60 gCO_2/km with a weight of 1,600 kg and a rate of USD 30 per gCO_2/km is calculated as 150 * 30 -/- 60 * 30 = 2,700 USD

The advantage of having a feebate system without attribute adjustments is the fact that the price signal given to consumers is the same for all vehicles. There is no risk of giving the same fee or rebate to vehicles with completely different performance levels. This in turn, reduces the risk of confusing the consumer and of being perceived as an unfair system[7] (ICCT, 2010).

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[7]   Note that in a flat system with a step-based feebate function this will still occur to some extent.

Figure 34   Feebate system design with no attributes
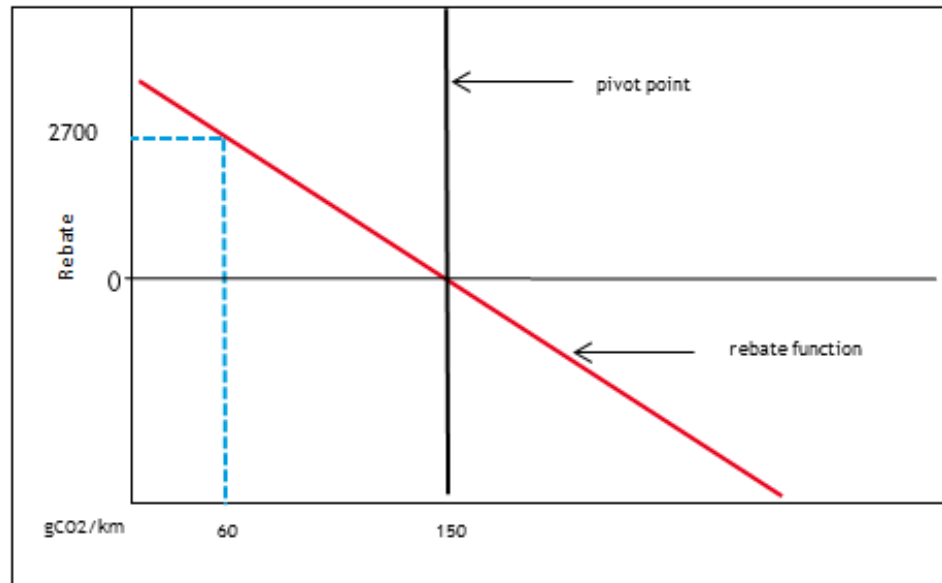
The implemented feebate (-like) schemes of France, the Netherlands, Ireland, and the US are examples of feebate systems with no attributes. A more detailed description of these schemes can be found in Annex B.

In the tool attribute adjustment is operationalized as a correction on the fee or rebate that would have applied in a feebate system with no attributes for the relative distance of a vehicle's or segment's attribute from the average of this attribute for the entire fleet of the country. However, as the relationship between an attribute and the metric (either fuel economy or CO_2 emissions per kilometer) is not linear, this correction needs to be flattened. The EU applies a slope of 60% for the relationship between mass and CO_2 in the EU CO_2 regulations for passenger cars (European Commission, 2012). Therefore this is assumed as the default in this tool as well (also for the other attribute adjustment options size and engine power). This is shown graphically in Figure 35. When considering the same example vehicle with 60 gCO_2/km, a weight of 1,600 kg that received a rebate of 2,700 USD without attribute adjustments, a weight-based attribute adjustment can be modelled as follows: 2,700 + 150 [pivot point] * 30 [rate] * 0,6 [flattening factor of the correction] * (1,600 [weight of the vehicle/segment] – 1,800 [average weight of the vehicle fleet]) /1,800 [average weight of the vehicle fleet] = **2,400 USD.**

Figure 35   Feebate system design with attribute
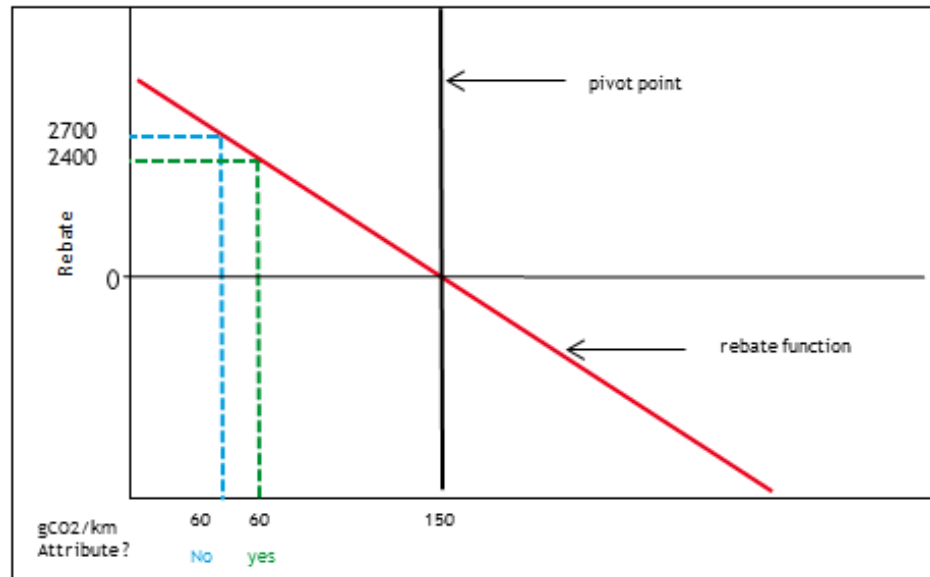
In the tool, the user choose between three attribute options: vehicle size, vehicle weight and engine power. As a default, **no attribute adjustment(s)** has(have) been applied.

With the **'attribute vehicle size'**, a mixed price signal can be given to consumers, as it can occur that two vehicles with different fuel consumption (and CO_2 emission) levels receive the same feebate if they differ in their size (ICCT, 2010). This in turn may confuse consumers. However, it may provide governments the opportunity to soften the impacts of the feebate scheme for larger cars (e.g. in order to increase the support of manufacturers for the feebate scheme or to remove consumers' feelings that the scheme is significantly interfering with their vehicle choice).

None of the feebate (-like) systems described in Annex B has implemented a scheme with the attribute of vehicle size.

The user can also choose for the **'attribute vehicle weight'**. It shares the same disadvantages and advantages as the previously described attribute vehicle size. However, it has one additional disadvantage, as this attribute will weaken the incentive to use light-weight materials in order to reduce emissions. A weight-based attribute adjustment reduces the rebate given to lighter vehicles and reduces the fee with which heavier vehicles are charged. Consequently, the benefit the manufacturer realises when applying lighter materials in terms of reduced fuel consumption is offset by the reduced rebate. With a size-based system this is not the case, and therefore, this attribute is preferred over a weight-based attribute.

None of the described feebate (-like) systems in Annex B uses vehicle weight as an attribute.

The **'attribute power'** (e.g. in HP) has been applied in some existing feebate(-like) systems although it has some serious disadvantages. This attribute reduces rebates for vehicles with low power and reduces fees for vehicles with high power. Consequently, this attribute provides an incentive to increase

power, which in turn will increase CO_2 emissions/fuel consumption.
It is therefore strongly recommended not to include this attribute adjustment.
The attribute engine power has been used in the German feebate-like system (see Annex B.6).

Box 5   **Attribute options not included in the tool**

Two other attribute adjustments have been mentioned in literature: fuel type and vehicle price (Peters et al., 2008). The '**attribute vehicle price**' has not been used in any of the described systems in Annex A. Although it may be one of the most important determinants of consumers' purchase decisions, it is also an aspect that manufacturers can adapt relatively easy, which may lead to strategic pricing by manufacturers. Therefore, it is not included as an option in the tool.

The '**attribute fuel type**' has been implemented in *Sweden (see Annex B.7) and the UK (see Annex B.8).* Although this attribute has the advantage of correcting for the differences in the CO_2 content of different fuels (in case a **fuel economy metric** is chosen), the current methodology with which the attribute adjustment has been modelled in the tool did not allow for this attribute to be included. I.e. the attribute correction is modelled with the relative distance of the attribute of a specific car/segment to the average value of this attribute for the entire fleet. It therefore requires a continuous variable, which is not the case for fuel type.

C.7   Point of administration

Tab in the tool: 'Feebate Design' – 'Advanced Design Options'
Location within tab: 'Budget control' button
Instruction for using the tool: Select the desired point of administration from the drop-down menu

The charged fees and granted rebates need to be administered. The point of administration that is chosen as the default option in the tool is the '**manufacturer level**'. The main advantage of choosing a feebate system that is administered at the manufacturer level is the fact that it will result in much lower administrative (and hence transaction) costs, as there are far less manufacturers with whom fees and rebates need to be exchanged.
The exchange of fees and rebates can be done at fixed points in time (e.g. once per year), further reducing transaction costs. A disadvantage of this point of administration is the lower impact on consumer choices. However, the main impact of feebates is argued to be on manufacturers (Greene et al., 2005), and will therefore still result in an effective system. Thereby, there are several ways to resolve this issue in practice, such as by obligating manufacturers to inform the consumer about the fee or rebate of the vehicles , which may result in an even higher effectiveness. This however will have higher monitoring and enforcement costs.

It is unclear which of the described feebate(-like) systems of Annex B have administered the exchange of fees and rebates at the manufacturer level.

The other option that is included in the tool is to chose the '**consumer level at the point of transaction**' as the point of administration. In this case, the fees and rebates are included in the purchase price. According to the ICCT (2010), a consumer-based system will have a larger impact on the purchase choice of consumers, and may therefore result in a more effective system. However, at the same time, such a system would be complex to administer (if no purchase

tax system has been implemented yet), and hence would have large transaction costs: fees and rebates need to be exchanged to a large number of consumers and at different points in time (as consumers buy cars throughout the year).

It is unclear which of the feebate(-like) systems that are described in Annex B have administered the exchange of fees and rebates at consumer level at the point of transaction.

Box 6   **Points of administration not included in the tool**

> Instead of choosing for a consumer level at the point of transaction, it is possible to use an 'indirect system at the consumer level'. In this case, consumers would have to apply for a refund on their paid vehicle purchase price/taxes from the government. However, this point of administration has the relatively highest transaction costs, as it requires consumers to fill out application forms and governmental employees to evaluate the applications. Therefore, it has not been included in the tool.

C.8   Pivot point adjustment

> **Tab in the tool:** 'Feebate Design'
> **Location within tab:** 'Pivot point control' (upper middle square of tab)
> **Instruction for using the tool:** Select the desired pivot point annual adjustment from the drop-down menu. If you choose the option 'Annual adjustment based on fixed criteria' or the option 'Lagged adjustment based on trigger', you can overwrite the shown underlying values.

As the fuel-efficiency of the fleet will improve over the years, it is advised to adjust the pivot point regularly. This can be annually, but it can also be done less regularly or only when a particular criteria has been met. If no adjustments are made the system's total levied fees may decrease and the rebates given may increase with the fuel-efficiency improvements of the fleet. Hence, ideally the pivot point needs to shift along with those improvements.

As a default, the pivot point is adjusted by means of **'annual adjustment based on observed changes',** which is the default option in the tool. This has the advantage of ensuring that the new pivot point is aligned with the actual situation (i.e. with actual/observed changes in fuel-efficiency). This in turn, will result in a lower risk of setting suboptimal pivot points and of having shortfalls as a result. A disadvantage of this option is the fact that it may confuse consumers. With annual changes, the same model of a manufacturer can be charged a different fee in two subsequent years (e.g. the 2013 and 2014 model), even though the vehicles are comparable in terms of their performance. Thereby, adjusting the pivot point with observed changes in the market will require more efforts in terms of research and communication, and hence in higher administrative costs of the system. Finally, manufacturers and consumers will have less certainty about how the pivot point will evolve over time, reducing their investment/purchase certainty.

It is unclear whether and which of the implemented systems described in Annex B have used annual adjustment of the pivot point based on observed changes.

The user can also choose for **'automatic annual adjustment based on fixed criteria'.** With this option, the pivot point is adjusted annually, and is shifted with fixed, predetermined, criteria. This percentage has to be kept constant

over the years in the tool, but could also increase or decrease after each year of operation in reality. Such a system would be relatively easy to implement, as it does not require significant research each year to determine the new pivot point. Therefore, the system will have relatively lower administrative costs. As the values have been predetermined, manufacturers and consumers will have certainty about future pivot points as well, which will provide manufacturers and consumers with investment and purchase certainty, respectively. Annual adjustment based on fixed criteria does have a significant disadvantage, as the actual efficiency improvements may differ significantly from the fixed criteria. If this occurs, the new pivot point(s) will be suboptimal, which can result in significant shortfalls in the governmental budget. Finally, as was the case with the other annual adjustment option, it may confuse consumers if a model receives a different rebate in two subsequent years.

The French feebate system provides an example of a scheme in which the pivot point has been adjusted with fixed criteria (see Annex B.1).

Two other options have been included in the tool, which do not require an annual adjustment of the pivot point. The user can choose for **'manual pivot point control'**. With this option, the user can choose a pivot point for the first year, which is not adjusted in later years. It has the same advantages as the previously described option: this option has the lowest administrative costs, is easiest to implement, and also provides investment and purchase certainty to manufacturers and consumers, respectively. However, the most significant disadvantage of this option is the fact that the pivot point is not adjusted although the vehicle fleet is likely to become more efficient. Consequently, the amount of fees will decrease and the amount of rebates will increase over the years, which may increasingly lead to shortfalls in the governmental budget. It is easy to explain to consumers though and prevents confusing them.

The fourth option included in the tool (**'Lagged adjustment based on trigger'**) does also not require a pre-determined (annual) adjustment interval. In this case, the intervals at which to re-set the pivot point are determined by consumer and manufacturer reactions to the feebate system, and the amount of fees and rebates paid. When the fleet's efficiency has been improved with a particular criterion (% efficiency improvement) the pivot point will shift with a pre-determined percentage as well. The shift in pivot point will be executed after a particular lead time (e.g. two years) after the criterion has been met. This option has the advantage that the pivot point does not have to be adjusted annually, and is only adjusted when this is necessary (i.e. when triggered by actual efficiency improvements). The lead time ensures that consumers and manufacturers are informed well in advance of the actual shift. Additionally, it can prevent confusing consumers as feebates do not change as frequently as is the case with annual adjustment options. This option has relatively higher administrative costs than the previous two options, but lower costs than annual adjustment based on observed changes. The lead time may cause some temporary shortfalls in governmental budget though until the pivot point is adjusted. This can also be the case for annual adjustment based on observed changes, but if the lead time is longer than one year, (temporary) shortfalls may be relatively larger.

Box 7   Pivot point adjustment criteria not included in the tool

There are several other options for adjusting the pivot point:
— immediate adjustment of the pivot point at the moment a specific criteria is met;
— random (i.e. irregular) adjustments based on observed changes.

Immediate adjustment of the pivot point when specific criteria are met has no set fixed timeframe for adjustments. Rather, the pivot point will be adapted in case specific criteria are met (e.g. a specific average fuel-efficiency is reached). This option has the advantage of preventing shortfalls in governmental revenues. However, continuous monitoring of the market will be required for this option and therefore requires a lot of analyses to be made, resulting in rather high administrative costs. Additionally, manufacturers and consumers have a low level of certainty with respect to when and how the pivot point will be adjusted. As a result of this option, it may be the case that the same vehicle model receives two different feebates in the same year. For all these reasons it is not included in the tool.

Making random adjustments also does not predetermine the occurrence of changing the pivot point. The pivot point can in this case be adjusted when policy makers decide the risk of shortfalls becomes too large, or in case shortfalls are already occurring for example. This does leave the policy maker with more flexibility as to when the pivot point will be adjusted (in contrast to fixed annual adjustments for example), reducing the risk that shortfalls will become too large. However, it does leave the market with complete uncertainty with respect to future pivot points changes, which may hamper innovations. For this reason, it is not included as an option in the tool.

Annex D User choices submodel

D.1   Introduction

This annex describes the implicit assumptions made in the feebate tool to simulate the results of the feebate system. Some of these assumptions can be adjusted in the 'Advanced Controls' sections.

D.2   The user choices submodel

Once the user has specified their desired feebate system, the purpose of the user choices submodel is to simulate the responses of agents to the new tax regime.

A feebate system alters the relative price of different vehicles. Specifically, it aims to make more-polluting vehicles relatively more expensive and, conversely, less-polluting vehicles relatively less expensive. The main aim of the system is to induce a shift in consumer demand, towards less-polluting vehicles as well as to send a signal to producers to invest in more energy-efficient technologies and thus, over a period of time, alter the general (energy-efficiency) mix of vehicles available in any given market. We would expect this to be the case in both the short and long terms. The consumer decision is the key component of the user choices submodel.

According to economic theory, in the short term, when manufacturers' production decisions (the range of vehicles offered) have already been set, a feebate system should have little or no effect on the supply-side of the market. This is because supply-side effects are generally attributed to the 'long term', i.e. a period over which manufacturers will be able to re-assess their production decisions. This then leaves short-term effects to be determined by consumer reactions, or 'the demand-side'.

However, this distinction is based on the (implicit) assumption that there is no distinction between local and global supply. When considering developing and transition countries, there may well be a difference between the range of available (i.e. within existing technological limits) vehicles that are supplied, and those that could be potentially available. This distinction is elaborated further in subsequent sections. Suffice to say that, as far as this current project is concerned, we consider 'supply-side effects' to relate to two types of effect. Firstly, the possibility that a different mix of vehicles (within existing technology) will be brought to market, most likely through import supply and through producers speeding up delivery of the models which are already in the production pipeline. Secondly, the extent to which manufacturers engage in product innovation and the development of vehicles with lower emissions rates than those currently available.

In the sections that follow, we outline the behavioural effects of interest for manufacturers and consumers, and the extent to which they can (or should) be captured in the final tool. We then describe how these two components fit into the proposed submodel, leading to the various output metrics from the tool.

D.3 Consumers

Holding all other factors constant, the introduction of a feebate system should lead to consumers purchasing more low-emissions vehicles, in lieu of the more-polluting vehicles that they would otherwise have bought. It does so by altering the relative price of different vehicles. More-polluting vehicles become more expensive and less-polluting vehicles become cheaper under a feebate system. Depending on the design of the feebate system, the policy may, in addition to shifting the composition of purchases, also lead to a change in the overall number of vehicles purchased.

In the tool, we propose to assess only the effect of price changes that come about from a feebate system. We do not, for example, propose to also allow for differences in household income between the feebate and no-feebate states of the world[8]. This limits the data requirements to information on factors whose price would be altered by a feebate scheme. Because the key effect of feebate systems is one of substitution between vehicle types, it will be important for the tool to differentiate between different types, i.e. some form of *segmentation/composition* representation, rather than simply a model of the *total number* of vehicles purchased.

This implies the following data requirements for the *current range* of available vehicles:
− vehicle retail prices;
− feebate/emissions-relevant vehicle attributes potentially subject to up-front (i.e. registration) taxes:
    − CO_2 emissions rates and/or fuel-efficiency (depending on the feebate metric);
    − other attributes that might be targeted by a feebate system, such as fuel type, engine size, weight, etc.[9]

At least in principle, (expected) running costs over the lifetime of the vehicle should affect demand but, as recent research suggests, consumers tend to focus more on the earlier, up-front costs[10], to the point that it would be reasonable to impose the simplifying assumption of circulation taxes and running (fuel and maintenance) to have no bearing on the consumer decision. Moreover, because the scope of the feebate systems is restricted to registration, rather than circulation, and because fuel costs will be assumed to be unchanged whether there is a feebate system in place or not, it is possible to ignore these effects in a comparison-to-baseline approach, as we do here.

D.4 Manufacturers (and distributors)

Because the focus of the feebate tool is on the long term, at least in principle, there should be some acknowledgement of supply-side effects. Although the research mentioned previously shows that the majority of feebate impacts come from producers rather than consumers, there is no evidence that that should be the case for developing and transition countries.

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[8] Although this is not to say that the starting point, the baseline, is necessarily unimportant, only that the tool must take this as a given, rather than attempt to generate a forecast itself.

[9] Chapter 4 discusses the data requirements in more detail.

[10] Possible explanations for this include higher discount rates further into the future (hyperbolic discounting) and loss-aversion under uncertainty regarding future fuel costs/savings.

In the short term, the range of vehicles (as defined by their emissions-related attributes) available for purchase is fixed, because manufacturers have already fixed their production decisions. However, in the long term, producers will be in a position to change their production decisions and thus respond to changes in market conditions.

It is important to distinguish between two types of production decisions:

— changes in the numbers of vehicles produced in each market segment:
  • e.g. production of more low-emissions vehicles, rather than high-emissions ones, because consumers now demand more of the former.
— changes in the range of vehicles produced in each market segment:
  • for the most part, this concerns the stimulation of innovation that leads to the development of vehicles that have lower emissions rates than those currently available in the market.

The first of these concerns supply-demand effects and is an effect that, for simplicity, we propose to model as demand-driven on the basis that the majority of developing countries that will make use of the tool will have small markets relative to the global supply of vehicles. Therefore it is reasonable in most cases to ignore the implications of excess demand leading to higher prices or of hard-and-fast supply shortages.

In this sense, any change in *composition of demand* within the technological range of vehicles available in a country (with respect to the CO_2 emissions) will be satisfied by the supply. Excess demand not met by indigenous supply will be covered by imports. Attributes not directly targeted by feebate systems are assumed to be constant.

The second source of supply-side effects is of more interest because policy interventions can, in principle, induce further innovation in the market. Note that by innovation we are referring to the introduction of vehicles with lower emissions rates than those available *globally*. The case where a country starts to import or produce vehicles that are identical (in attribute terms) to those in existence elsewhere in the world can be considered an example of the first form of supply-side effect.

In most countries, the size of the feebate system effect and the size of the country's consumer market are likely to be too small to actually shift the frontier of low-emissions vehicles from a unilateral policy intervention. To that extent, in most cases, it seems acceptable to impose the simplifying assumption that the frontier of low-emissions technology is external (exogenous) to the country and that consumers are simply choosing from a fixed range of vehicles (though that range of choice may still change over time).

Of course, it is not the case that every possible vehicle for sale is actually purchased by consumers in a single country. Indeed, most countries' vehicle fleets will be far from the most efficient vehicles on the market. What we are instead assuming is that, for whatever reason, consumers in a country demand a particular range of vehicles from the wider global subset. Shifts in consumer demand as a result of the feebate system may well lead to purchases of vehicles not currently on the roads, but these vehicles will not be new in a global sense.

D.5 Modelling and parameterization

The results simulated with the Feebate Tool hinge on design of the feebate system and the subsequently computed response from consumers and producers.

The design of feebate system is made flexible for a user to experiment with, however the market response is modelled rigorously to reflect what would be likely to happen if the designed scenario is implemented.

Consumers and producers are the two economic agents whose behaviour will determine outcome of a feebate system. The consumers are expected to demand more of the now cheaper (less-polluting) vehicles, and producers are expected to shift their production towards cars with lower CO_2 emissions.

The magnitude of the behavioural effects is governed by parameters (elasticities). We discuss modelling solutions and choice for parameters for consumers and producers in turn below.

Consumers
To model consumers purchasing decisions, we adopt a cascading structure which reflects the sequential process followed by consumers when buying a vehicle.

Figure 36   Modelling consumer decision process
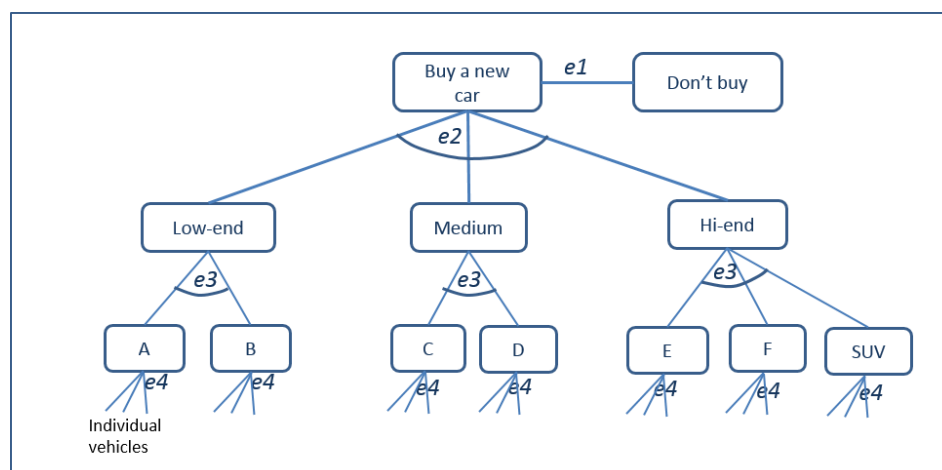
Figure 36 represents the nested decision process for a consumer who is to buy a car with respect to different substitution possibilities across different segments.[11] Firstly, a consumer decides whether he needs a new vehicle or not, with elasticity *e1*. If the consumer decides to but a vehicle, he opts for one of the three main groups: high-end vehicle, medium or low-end car. We assume that consumers will have rather strong preferences for one of the four main groups because of specific needs that the car is to fulfil. Hence, a person who requires a small commuter car is not going to buy off-road or a luxury car. This limited substitution is determined by relatively low value of elasticity *e2*.

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[11]   The nested consumer demand for vehicles is modelled with Constant Elasticity of Substitution (CES) function as commodity aggregator. This solution allows for different degrees of substitution for different decision options.

Once a consumer decides on one of the four main groups, a set of options he is likely to consider is widening. For example, if someone has decided for a medium car, he is willing to consider lower medium, medium and upper medium cars and more easily substitute one for another if, for example, one of the segments is subjected to a feebate scheme benefit. That higher degree of substitution is represented by relatively higher value of elasticity *e2, e3* and *e4*.

The system is modelled with linearised Constant Elasticity of Substitution (CES) function[12].

$$c_i = c - e(p_i - p)$$

Where c_i is the percentage change in demand for vehicle i, c is percentage change in demand for a group of vehicles to which the vehicle i belongs, p_i is percentage change in price of vehicle i, p is percentage change in aggregate price for the group of vehicles to which i belongs, and e is the elasticity of substitution.

The price is aggregates as in:

$$p = \sum_i \delta_i p_i$$

Where δ_i is the cost share of vehicle i in the group of the vehicles ($\sum_i \delta_i = 1$)

Since the feebate tool demand system consists of four consumer decision layers, it requires separate specification for each of the nested functions. Hence, the whole demand system consists of set of demand equations:

Individual cars: $\qquad c_4 = c_3 - e_4(p_4 - p_3)$

Segments: $\qquad\qquad c_3 = c_2 - e_3(p_3 - p_2)$

Groups: $\qquad\qquad\ c_2 = c_1 - e_2(p_2 - p_1)$

Total demand: $\qquad\ c_1 = e_1 p_1$

And the set of price equations:

Individual cars: $\qquad p_4 = \dfrac{price\,of\,car + rabate}{price\,of\,car}$

Segments: $\qquad\qquad p_3 = \sum \delta_4 p_4$

Groups: $\qquad\qquad\ p_2 = \sum \delta_3 p_3$

Final demand price: $\ p_1 = \sum \delta_2 p_2$

The feebate system works by changing the relative price of individual vehicles (p_4) which then determines change in demand and aggregate prices for all the segments and groups.

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[12] See the box at the end of this annex for linearization of the CES function.

For consumers, the main behavioural parameter is the price elasticity of demand for new vehicles, which links a change in price of vehicles with change in quantity demanded. It is a negative number, although the sign is often omitted, and the lower the value the more sensitive consumer demand is to variation in price. The review of existing studies revealed that all of the relevant analyses undertaken are for developed countries and so there are no reports about impact of feebate/taxation on demand for cars in developing countries. For this reason we adopt values for elasticities from the existing literature as initial parameters for the model, but also give the user an option to modify these parameter values if better estimates are identified or considered more valid.

Existing studies suggest that the demand elasticity for cars takes value of about -2, which means that a 1% increase in price of a car leads to 2% decline in sales of this type of car. The elasticities also tend to differ across demographics, such as income level or urban versus rural population areas. For our study the relevant values are different elasticities for cheaper cars (about -1.9) and luxury cars (about -2.3), which will be used to reflect different substitutability between the car segments, as discussed below with aid of Figure 36. The Feebate Tool is parameterised based on Kleit (2004)[13] study, which provides a detailed overview of vehicles' elasticities:

Figure 37   Demand elasticities of different vehicle classes

		1	2	3	4	5	6	7	8	9	10	11
1	Small Car	-2.808	0.423	0.063	0.018	0.000	0.036	0.027	0.009	0.009	0.009	0.000
2	Medium Car	0.684	-3.528	1.107	0.027	0.018	0.018	0.018	0.036	0.045	0.054	0.009
3	Large Car	0.270	1.926	-4.500	0.027	0.216	0.009	0.054	0.018	0.063	0.054	0.009
4	Sport Car	0.549	0.423	0.324	-2.250	0.009	0.090	0.198	0.045	0.108	0.018	0.000
5	Luxury Car	0.045	0.405	1.062	0.009	-1.737	0.000	0.027	0.045	0.189	0.072	0.009
6	Small Truck	0.162	0.099	0.000	0.009	0.000	-2.988	0.702	0.045	0.054	0.009	0.009
7	Large Truck	0.063	0.072	0.018	0.009	0.000	0.234	-1.548	0.027	0.090	0.018	0.036
8	Small SUV	0.216	0.279	0.099	0.027	0.009	0.090	0.351	-3.645	0.747	0.108	0.072
9	Large SUV	0.117	0.243	0.171	0.018	0.018	0.054	0.387	0.414	-2.043	0.234	0.108
10	Minivan	0.081	0.171	0.063	0.000	0.009	0.009	0.045	0.027	0.135	-2.286	0.180
11	Van	0.027	0.036	0.009	0.009	0.000	0.009	0.054	0.036	0.072	0.387	-2.385

Source: Kleit (2004).

Manufacturers/distributors

The main supply-side effect accounted for the in the feebate tool is reduction in CO_2 emissions implemented in new vehicles in response to the feebate system. This effect is brought about by manufacturers who provide newer, technologically advanced model of vehicles with lower emissions and/or improved fuel economy.

The magnitude of manufacturers' reaction to feebate is schematically depicted in Figure 38. Producers decide to improve CO_2 emissions in manufactured vehicles only if additional potential revenue, FN, due to feebate system which they expect to realize from sales to a given car segment is greater than some minimum pivot point value FN_{MIN}. Then, the higher the expected revenue FN the greater would be the implemented improvement in fuel economy.

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[13]   Kleit, A.N. 2004. 'Impacts of Long-Range Increases in the Fuel Economy Standards', Economic Inquiry, vol. 42, no. 2. Pp. 279-294.

Figure 38   Manufacturers' response to feebate scheme
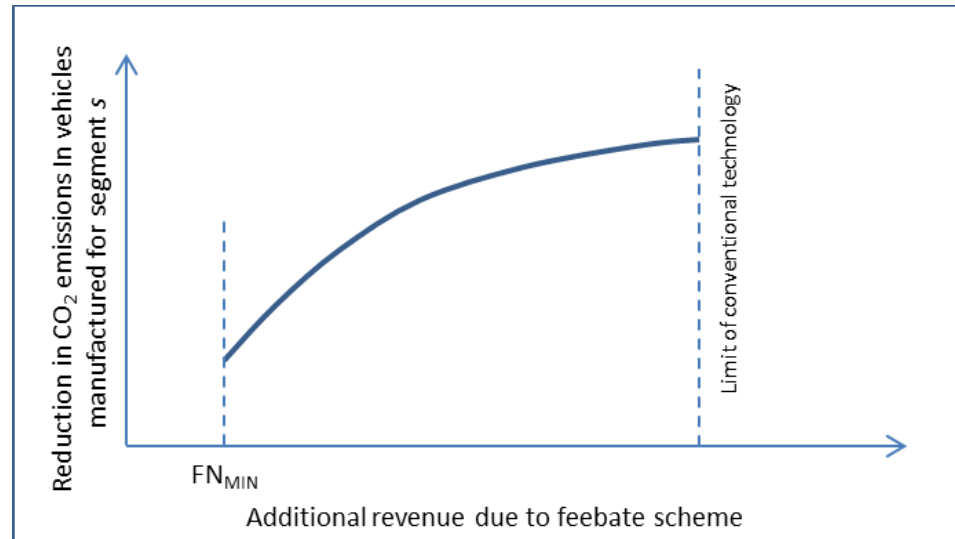
The additional revenue that manufacturers expect to make will depend not only on the magnitude of feebate system for a particular segment, but also on the size of the vehicle/segment market in the country. Even if the feebate rates are set relatively high but quantity of demand on the local market is not sufficient, then producers may not decide to equip new vehicles with better technology. Therefore, the potential revenue (and its minimum value FN_{MIN}) will be country- and segment-specific and calculated as multiplication of the feebate rate and of expected quantity of vehicles sold.

The supplier reaction function is modelled as:

Formula 1: $\%\Delta CO_2 = max\left[0, \left(\alpha \frac{FN}{FN_{MIN}}\right)^{\beta}\right]$

Where α and β are the parameters to calibrate the function.

The factors of interest here are: the parameter that links the CO_2 reduction with size of the feebate, and timing of the supply response. The former is discussed in the paragraph below; the latter is discussed in the next section.

Quantitative evidence for producers' behaviour in response to feebate schemes is even scarcer than for consumers. The only study that aimed to estimate producers' cost of improving fuel economy is Green and Brunch (2011). The study estimates that implementation of 10% improvement in fuel-efficiency costs producers approximately USD 280 per vehicle in short run (2007-2014), and USD 210 in long run (2020-2030). Those values were estimated for the US market and they may not accurately reflect manufacturers' decisions on other markets, particularly for developing and transition countries, and hence should be used as indicative.

In practice, this mechanism will be implemented by controlling the CO_2 emissions of the base data of vehicles. For example, if in a country the average CO_2 emissions of vehicles offered for sale in segment Medium were 150g CO_2/km, after implementation of the feebate system the average CO_2 emissions of vehicles offered in this segment can decrease by e.g. 4% to 144 g CO_2/km. It is equivalent to say that, at a micro-level, a vehicle with

certain emission characteristic offered for sale at a certain price after implementation of a feebate system will be offered for sale as a new model at the same price but with improved fuel economy, i.e. with reduced CO_2 emissions. Timing of those responses is discussed in Section D.7.

D.6 Issue of timing

In most applications, it is sufficient for the tool to assess the impacts of a feebate system at a single point in the future (the long term). However, at present there are two cases where a period-by-period analysis will be of interest:

− where the user might be interested in the time path of the projected revenues[14];
− where the model is to account for the supply-side effects leading to introduction of new-to-market vehicles and stimulating further demand response.

The literature indicates that the demand response to introduction of feebate systems is more immediate than the supply response. The price elasticities of demand reviewed in previous section were based on analysis of data covering one to three years following introduction of a feebate scheme. On the other hand, the producers are reported to respond to the feebate incentive as quickly as within a year after its introduction in case if they only bring forward technological improvement that are already in the pipeline, or as late as seven years after introduction of feebate in case of more fundamental innovations. The feebate tool addresses this differential timing of producers' response to feebate scheme by assuming an initial transition period of three years over which producers gradually bring the new technology to the market, before being able to fully offer the technology as defined by Formula 1 in the previous section.

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[14] And, indeed, where continual adjustment of the pivot point and/or feebate slope/steps may be necessary to maintain revenue neutrality. We do note, however, that continual adjustment of the feebate function may introduce an element of uncertainty to the policy that may adversely affect uptake (because consumers and producers will be operating under greater uncertainty).

Linearisation of the CES function

The standard CES commodity aggregator takes the form of:

$$C = \left(\sum_i \left(\delta_i C_i \right)^{\frac{\sigma-1}{\sigma}} \right)^{\frac{\sigma}{\sigma-1}}$$

And derived demand:

$$C_i = C \delta_i \left(\frac{P_i}{P} \right)^{-\sigma_i} \text{ where } P = \left(\sum_i \left(\delta_i P_i \right)^{1-\sigma} \right)^{\frac{1}{1-\sigma}}$$

Where C is the total demand for cars, C_i is demand for a specific segment cars, δ is a share parameter, and σ_i is elasticity of substitution.

The function is linearised by total differentiation:

$$dC_i = dC \delta_i \left(\frac{P_i}{P} \right)^{-\sigma} - \sigma C \delta_i \left(\frac{P_i}{P} \right)^{-\sigma} \frac{dP_i}{P_i} + \sigma C \delta_i \left(\frac{P_i}{P} \right)^{-\sigma} \frac{dP}{P}$$

And by dividing by C_i to obtain expression in percentage changes:

$$c_i = c - \sigma \left(p_i - p \right)$$

Similarly (totally differentiate and divide by P) for the price index to obtain:

$$p = \sum_i \delta_i p_i$$

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