Transport Pricing Guidance

Guidance for assessing the greenhouse gas impacts of transport pricing policies

May 2018

How to assess impacts for vehicle purchase incentives and road pricing

10. ESTIMATING GHG IMPACTS FOR VEHICLE PURCHASE INCENTIVES AND ROAD PRICING

This chapter provides supplementary guidance on estimating GHG impacts for vehicle purchase incentives and road pricing policies. The guidance document has focused on helping users estimate the impacts of higher fuel prices using price elasticities of demand. This chapter provides a condensed approach to help users estimate the impacts of purchase incentives for highly efficient vehicles and road pricing policies.

10.1 Overview of vehicle purchase incentives and road pricing

Many of the same considerations for quantifying the impacts of fuel price increases (see Chapters 7, 8 and 9) also apply to other pricing policies. However, there are two key differences:

- Fuel price increases generally affect the entire vehicle fleet, or at least the entire gasoline- or diesel-fuelled sub fleet. In contrast, road pricing policies often affect only a particular geographic region, a particular time of day, or a particular market segment, such as employee commutes to work.

- Fuel price increases reduce GHG emissions through two major channels, namely reducing vehicle travel and improving fuel economy, while most other pricing policies only reduce emissions through one channel. For example, road pricing only reduces vehicle travel, and usually does not encourage a switch to the use of more efficient vehicles. Incentives for highly efficient vehicles only improve fuel economy or encourage a switch to lower-carbon fuels, but do not reduce vehicle travel.

10.2 Purchase incentives for low-GHG vehicles

10.2.1 Overview of purchase incentives

Governments increase the fuel efficiency of the vehicle fleet and/or promote a shift to lower-carbon fuels through providing incentives for the purchase of selected vehicles. This policy is most applicable to electric, plug-in hybrid-electric, hydrogen-fuelled and other vehicles that are not powered by gasoline or
diesel. However, it can also be applied to highly efficient gasoline or diesel vehicles, such as hybrid-electric vehicles, where the technology is embryonic or commands a low market share.

Governments can provide a range of purchase incentives, including:

- **Lower purchase taxes**: Reduce the cost of purchasing a low-GHG vehicle through providing tax incentives at the point of sale. For example, Hong Kong waives the First Registration Tax for electric private cars up to a maximum of HKD 97,500 (~USD 25,000). Commercial electric vehicles and electric motorcycles in Hong Kong are also eligible for tax concessions.\(^1\) India and Malaysia also reduce excise duties for some hybrid-electric and battery-electric vehicles.

- **Purchase rebates**: Reduce the cost of purchasing a low-GHG vehicle through rebates or similar purchase incentives. These programmes work in a similar way to lower purchase taxes, but the rebate is claimed at a later date rather than applied at the point-of-sale. For example, Sweden’s SEK 40,000 (~USD 4,400) rebate for new cars that achieve a threshold level of emissions was introduced in 2012.\(^2\) In France and Portugal, rebates can be more than doubled if an eligible vehicle (e.g., a diesel car) is scrapped at the same time.\(^3\)

- **Income tax credits**: Reduce the cost of purchasing a low-GHG vehicle or equipment such as home chargers, through providing incentives that can be claimed at a later date via an income tax credit. For example, in the United States an income tax credit of up to USD 7,500 was offered for the purchase of certain electric vehicles.

- **Lower vehicle taxes**: Reduce the annual costs of owning a low-GHG vehicle through lowering or eliminating annual registration fees or vehicle taxes. For example, China exempts electric vehicles from annual registration taxes.\(^4\)

10.2.2 Success factors for purchase incentives

The design of purchase incentives has a significant impact on their effectiveness in increasing the market share of low-GHG vehicles, and in reducing emissions. Table 10.1 summarises some of the success factors.

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\(^2\) Transport Styrelsen. Available at: [https://www.transportstyrelsen.se/sv/vagtrafik/Fordon/Supermiljobilspremie/](https://www.transportstyrelsen.se/sv/vagtrafik/Fordon/Supermiljobilspremie/).

\(^3\) OECD/IEA 2016.

Table 10.1: Factors that increase the effectiveness of purchase incentives for low-GHG vehicles

<table>
<thead>
<tr>
<th>Factors</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Incentive structure</td>
<td>The closer the incentive to the point-of-sale, the greater the impact on purchase decisions. For example, sales tax exemptions have a greater impact than income tax exemptions that must be applied for at a later date.</td>
</tr>
<tr>
<td>Programme durability</td>
<td>Longer-term, predictable incentive programmes can give manufacturers the certainty to invest and bring more low-GHG vehicles to market, and provide better marketing for consumers.</td>
</tr>
<tr>
<td>Individual eligibility</td>
<td>Incentives that are limited to lower-cost vehicles or targeted to lower-income consumers can reduce the total impact of an incentive programme (measured in tCO₂e reduced), but improve its cost-effectiveness (cost per tonne reduced).</td>
</tr>
<tr>
<td>Technology eligibility</td>
<td>Focusing on new technologies with minimal market share, such as battery-electric vehicles, is likely to improve the cost-effectiveness of an incentive program. Allowing mature technologies such as hybrid-electric vehicles to qualify means that incentives will go to many people who would have purchased that low-GHG vehicle anyway.</td>
</tr>
<tr>
<td>Scrappage</td>
<td>Programme effectiveness can be improved by requiring scrappage of a high-emission vehicle to qualify for the incentive, or by providing an enhanced incentive.</td>
</tr>
<tr>
<td>Impact on high-emission vehicles</td>
<td>The most effective programmes not only provide incentives to purchase low-GHG vehicles, but impose fees or other disincentives on high-GHG vehicles. Such programmes can be structured in the form of a revenue-neutral “feebate,” or a combination of fee and rebate.</td>
</tr>
</tbody>
</table>

10.2.3 Impacts of purchase incentives

Figure 10.1 provides an example causal chain for purchase incentives for low-GHG vehicles. The most direct impact of purchase incentives on GHG emissions is the increase of the market share of electric, hybrid and other efficient vehicles, which reduces emissions per kilometre travelled either through greater fuel efficiency or through a shift to lower-carbon fuels. In the longer-term, an even greater impact on emissions may occur through technological improvements, as vehicle manufacturers gain experience with new fuels and exploit economies of scale.

Purchase incentives can increase emissions in two ways. First, low-GHG vehicles are likely to be cheaper to drive because they are more fuel-efficient and/or because fuels such as compressed natural gas or electricity cost less per unit of energy, in particular if these fuels are tax-exempt or taxed at a lower rate. The lower cost per kilometre driven may increase vehicle travel – a rebound effect. Second, if low-GHG vehicles are cheaper to purchase, overall car ownership may increase.

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5 For example, DeShazo, JR; Sheldon, T and Carson, R. 2016. Designing Policy Incentives for Cleaner Technologies: Lessons from California’s Plug-in Electric Vehicle Rebate Program. Available at: http://innovation.luskin.ucla.edu/content/designing-policy-incentives-cleaner-technologies-lessons-california%E2%80%99s-plug-electric-vehicle-.

Figure 10.1: Example causal chain for purchase incentives for low-GHG vehicles

In the causal chain, increased emissions due to the rebound effect (higher levels of car ownership) and the impact (reduced GHG emissions from vehicle travel due to long-term improvements in technology) may be considered to cancel each other out, and thus would not be included in the GHG assessment boundary.

The track record of purchase incentives in expanding the market share of low-GHG vehicles is mixed. Some studies find no effect, while other studies find a measurable impact on GHG emissions. When expressed in the cost per tCO\(_2\)e reduced, USD 100-300 is a typical range.\(^7\) The impact of purchase incentives depends on several factors summarised in Table 10.1. A general rule, however, is that purchase incentives and other policies that target the fixed costs of vehicle ownership tend to have a lesser impact compared to policies that target the variable costs of vehicle operation, such as fuel taxes.

10.2.4 Simple approach for calculating the GHG impacts of purchase incentives

Given the range of programme design and other factors that affect the impact of purchase incentives, this guidance recommends a simplified approach based on the aggregate relationship between electric vehicle (battery-electric and plug-in hybrid-electric) market share, and the cost premium (net of incentives) for electric vehicles. Such a simple approach does not account for all of the impacts shown in the causal chain; the assumption is that the non-quantified impacts cancel each other out, or are within the overall range of uncertainty.

Note that this simplified method does not account for the many other factors that affect EV market share, and the relationship between cost and market share is likely to change as EV technology matures. Further uncertainty is introduced when applying the method to other technologies, such as hydrogen or compressed natural gas. Caution and professional judgment is needed in these circumstances.

Follow the steps below for a simple approach to calculate the GHG impacts of purchase incentives:

**Step 1: Calculate the average value of the rebate, as a percentage of the vehicle retail price**

- For reductions in ad valorem sales taxes or excise duties, this step is straightforward. For example, a reduction in tax from 20% to 15% equates to a fraction of $0.05 / 1.2 \times 100 = 4.2\%$.
- For flat-rate rebates and similar incentives, the sales-weighted average retail price of eligible vehicle models should first be calculated. For example, if the sales-weighted average price of low-GHG vehicles is USD 50,000, a USD 1,000 rebate is equal to a fraction of 2%.

**Step 2: Estimate the change in market share of low-GHG vehicles**

- Use the following equation:

  \[
  \text{Market share (percentage – point change)} = \beta \times \text{average rebate value [from Step 3a]}
  \]

  The 0.3 value is derived from aggregate market data and the judgment of the author team.

  For example, a rebate worth 2% is estimated to translate into a $2 \times 0.03 = 0.06\%$ percentage point increase in low-GHG market share (for example, from 0.50% to 0.56% of the market).

**Step 3: Estimate the per-km emission reductions from low-GHG vehicles**

- Emission factors (CO$_2$e km$^{-1}$) for both eligible low-GHG vehicles and the existing vehicle fleet can be calculated as discussed in Chapter 7 on baseline emissions. The difference between the two represents the per-km emission savings from low-GHG vehicles.

**Step 4: Calculate GHG impacts**

- Use the following equation:

  \[
  \text{GHG impact} = \text{Market share (percentage – point change)} \times \text{annual new vehicle sales} \times \text{per km emissions reduction} \times \text{average lifetime km per vehicle}
  \]
Where:

- Market share is calculated in Step 2
- Annual new vehicle sales is obtained from official national statistics, and be consistent with the market definition in Step 2. For example, if Step 2 refers to the low-GHG share of the passenger car market (i.e., excluding commercial vehicles), annual new vehicle sales should refer to passenger cars only
- Per-km emissions reductions are calculated in Step 3
- Average annual km per vehicle is estimated using national statistics on annual vehicle km and vehicle lifespan. In their absence, a default value of 15,000 km per year can be used.\(^8\)

### 10.2.5 Advanced approach for calculating the GHG impacts of purchase incentives

Where more data on vehicle prices, technologies and consumer demand are available, and econometric expertise is available, more advanced approaches can be used to estimate the GHG impacts of purchase incentives. These advanced approaches will capture local market dynamics in a more sophisticated way than the simple approach presented in Section 10.1, and can also be applied to a wider range of vehicle technologies. The focus of the references listed below is on simulation models and other approaches that can predict the impact on incentive programmes, rather than ex-post analyses.


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10.3 Road pricing

10.3.1 Overview of road pricing

National and local governments can reduce vehicle travel through charging distance-based fees to use particular roads, or for access to city centres. Road pricing policies can be implemented in several different ways:

- **Cordon pricing**: Drivers must pay to enter the tolled area, typically a city center or regional core. Singapore, London, Rome and Stockholm are some of the most notable examples.

- **Toll roads**: Drivers must pay for access to a particular link in the roadway network, often a bridge or tunnel. Toll roads are the most common implementation of road pricing.

- **Distance-based charges**: Vehicles are equipped with a GPS-based recording device, and drivers are charged per kilometre driven. Switzerland, for example, charges fees to heavy vehicles based on weight, emission levels and the distance driven. Annual odometer audits can also be used. Many European countries have implemented distance-based charges for heavy good vehicles.

10.3.2 Impacts of road pricing

Figure 10.2 shows an example causal chain for road pricing policies. The primary impact of the increase in driving costs per kilometre travelled is reduced vehicle travel within the cordon or on the priced facility, which results in reduced emissions. The reduction in vehicle travel occurs through two main channels: a reduction in overall trip-making, and a modal shift to walking, bicycling, public transport and carpooling. The degree of modal shift will depend on the quality of these substitutes – for example, cities such as London with high-quality buses and trains will experience a greater shift towards public transport.

A secondary emission reduction impact can occur if reductions in congestion allow vehicles to operate more efficiently, through reductions in vehicle idling or operations at inefficiently low speeds.

The reduction in emissions is likely to be partially offset by a shift in vehicle travel to non-priced facilities. For cordon pricing, the smaller the cordon, the greater this substitution effect is likely to be. For toll roads, the extent of the substitution will depend on the availability of alternative, parallel routes.

Other emissions impacts depend on how pricing revenue is used. Cities such as London primarily use the revenue to expand public transport and non-motorised transport facilities, which is likely to reinforce emission reductions given that public transport emissions are likely to be relatively small. Many road tolling policies, in contrast, use the revenue to expand roadway capacity, which is likely to increase emissions. In these cases, emissions from the additional travel induced by road congestion is likely to offset the emission savings from road pricing, and estimating the additional vehicle travel and emissions is beyond the scope of this guidance. This guidance does not apply to policies that provide fee-based access to dedicated “express lanes” or a similar less-congested facility, while leaving other lanes free of charge.
10.3.3 Simple approach for calculating the GHG impacts of road pricing policies

The impact of cordon pricing can be estimated based on the experience of similar cities. The impact of toll roads and distance-based charges can be quantified more precisely using price elasticities of demand. Follow the steps below for a simple approach to calculate the GHG impacts of road pricing policies.

**Cordon pricing**

**Step 1: Estimate vehicle travel within the cordon**, by vehicles that would be subject to the charge (vehicle km year$^{-1}$). Travel by exempt vehicles (e.g., taxis) should be excluded, as should travel outside the hours of operation.

**Step 2: Estimate the change in vehicle travel**, through applying a percentage reduction to the vehicle travel estimated in Step 1. A default reduction of 20% is recommended, based on the experiences in cities that have implemented cordon pricing, where reductions range from 10% to 44%.\(^9\) This assumes that the price is in a similar range to previously implemented programmes in cities such as London (~USD 14 per day), Stockholm (up to ~USD 4 per day per entry or exit), and Singapore (up to ~USD 4.25 per entry or exit). However, project-specific estimates may be available from a travel demand model or similar source.

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Step 3: Convert the change in vehicle travel to a change in emissions using the emission factors as calculated with the guidance in Chapter 7.

Toll roads and distance-based charges

Step 1: Estimate vehicle travel on the priced facilities (vehicle km year\(^{-1}\)). For toll roads, annual traffic volume data are required. For distance-based charges, data for the subset of the vehicle fleet that is subject to the charges are required, such as the distance travelled by heavy good vehicles.

Step 2: Estimate the fractional increase in driving costs, considering both fuel cost and the toll charge per kilometre. The fuel cost is a function of the per-litre cost of fuel and the vehicle fuel economy (calculated with the guidance in Chapter 8). Use the equations below.

Equation 10.3: Estimate the fractional increase in driving costs

\[
\text{Fuel cost per km} = \text{Fuel price per liter} \times \text{Fuel economy (liters per km)}
\]

\[
\text{Increase in driving costs} = \frac{\text{Toll increase (per km)}}{\text{(Existing toll per km + fuel cost per km)}}
\]

Step 3: Apply a price elasticity of vehicle travel to the increase in driving costs estimated in Step 2, and multiply by the vehicle travel estimated in Step 1, using the equation below.

Equation 10.4: Estimate change in vehicle travel

\[
\text{Change in vehicle travel (km)} = \text{vehicle travel elasticity} \times \text{increase in driving costs (\%)} \times \text{vehicle travel (km)}
\]

The fuel-price elasticities presented in Chapter 8 are not directly applicable to toll roads or distance-based charges. In the case of fuel-price increases, consumers can respond by choosing more fuel-efficient vehicles and/or driving less. With toll roads and distance-based charges, only the second channel is the main response. Thus, the vehicle travel elasticity in Step 3 will be lower than those presented in Chapter 8.

If local elasticities are available, these can be used in Step 3. Otherwise, multiply the fuel-price elasticity from Chapter 8 by 0.45.\(^{10}\) For example, if the fuel-price elasticity is -0.30, then the vehicle travel elasticity would be -0.30 x 0.45 = -0.135.

The assumption is that substitution effects shown in the causal chain are small.

Step 4. Convert the change in vehicle travel to a change in emissions, using the emission factors calculated with the guidance in Chapter 7.

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\(^{10}\) Goodwin, P, Dargay, J and Hanly, M 2004. The mean fuel consumption elasticity is -0.64, while the vehicle km elasticity is -0.29.
10.3.4 Advanced approaches for calculating the GHG impacts of road pricing

More advanced approaches can be used to estimate the GHG impacts of road pricing policies. In general, a regional travel demand model will be required that can predict the impact of different prices on travel, mode share and congestion. For further information, refer to the following:

