10 Estimating GHG impacts for vehicle purchase incentives and road pricing

This chapter provides supplementary methods for estimating GHG impacts of vehicle purchase incentives and road pricing policies. Previous chapters of the methodology have 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 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 subfleet. 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: reducing vehicle travel and improving fuel economy. Most other pricing policies reduce emissions through only 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 improve fuel economy or encourage a switch to lower-carbon fuels, but do not reduce vehicle travel.

If several policies or measures are implemented simultaneously[56] as a mutually reinforcing package, the policies and measures can be assessed together as a package of policies. An example of such a package is a levy on fossil fuels used in fossil-fuelled vehicles to discourage their use, purchase incentives for low-GHG-emission vehicles (such as electric vehicles) to encourage their market uptake, and road pricing and efficient parking pricing that discourage the use of fossil-fuelled vehicles and encourage the use of low-GHG-emission vehicles. The assessment of the package needs to take into account the timing and the specific type of measures (see Section 5.2 and Chapter 5 of the *Policy and Action Standard*). Note that, when assessing a package of policies, there may be overlaps or interactions between the policies being assessed.

10.2 Purchase incentives for low-GHG vehicles

10.2.1 Overview of purchase incentives

Governments can increase the fuel efficiency of the vehicle fleet and/or promote a shift to lower-carbon fuels by 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 the following:

- **Lower purchase taxes** – reduce the cost of purchasing a low-GHG vehicle by 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 HK$ 97,5000 (~US$ 25,000). Commercial electric vehicles and electric motorcycles in Hong Kong are also eligible for tax concessions.[57] India and Malaysia also reduce

[56] If the policies or measures are not implemented simultaneously (i.e. one measure has already been implemented in the past), the impact of the already implemented measure is reflected in the baseline, and the impacts of the policies and measures cannot be combined.

[57] Hong Kong Environmental Protection Department (2019).

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 (~US$ 4,400) rebate for new cars that achieve a threshold level of emissions was introduced in 2012.[58]

- **Income tax credits** – reduce the cost of purchasing a low-GHG vehicle or equipment such as home chargers, by 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 $7,500 was offered for the purchase of certain electric vehicles.

- **Lower vehicle taxes** – reduce the annual costs of owning a low-GHG vehicle by lowering or eliminating annual registration fees or vehicle taxes. For example, China exempts electric vehicles from annual registration taxes.[59]

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 summarizes some of the success factors.

TABLE **10.1**

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

Factor	Description
Incentive structure	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.
Programme durability	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.
Individual eligibility	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 tCO_2e reduced), but improve its cost-effectiveness (cost per tonne reduced).
Technology eligibility	Focusing on new technologies with minimal market share, such as battery-electric vehicles, is likely to improve the cost-effectiveness of an incentive programme. 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.[60]
Scrappage	Programme effectiveness can be improved by requiring scrappage of a high-emission vehicle to qualify for the incentive, or by providing a larger incentive.
Impact on high-emission vehicles	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" (a combination of fee and rebate).[61]

58 Transport Styrelsen (no date).

59 Yang et al. (2016).

60 For example, DeShazo, Sheldon and Carson (2016).

61 For a discussion of feebates, see German and Meszler (2010).

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 an increase in 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 CNG or electricity cost less per unit of energy, particularly 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.

In the causal chain, increased emissions due to the rebound effect (higher levels of car ownership) and the impact of 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.

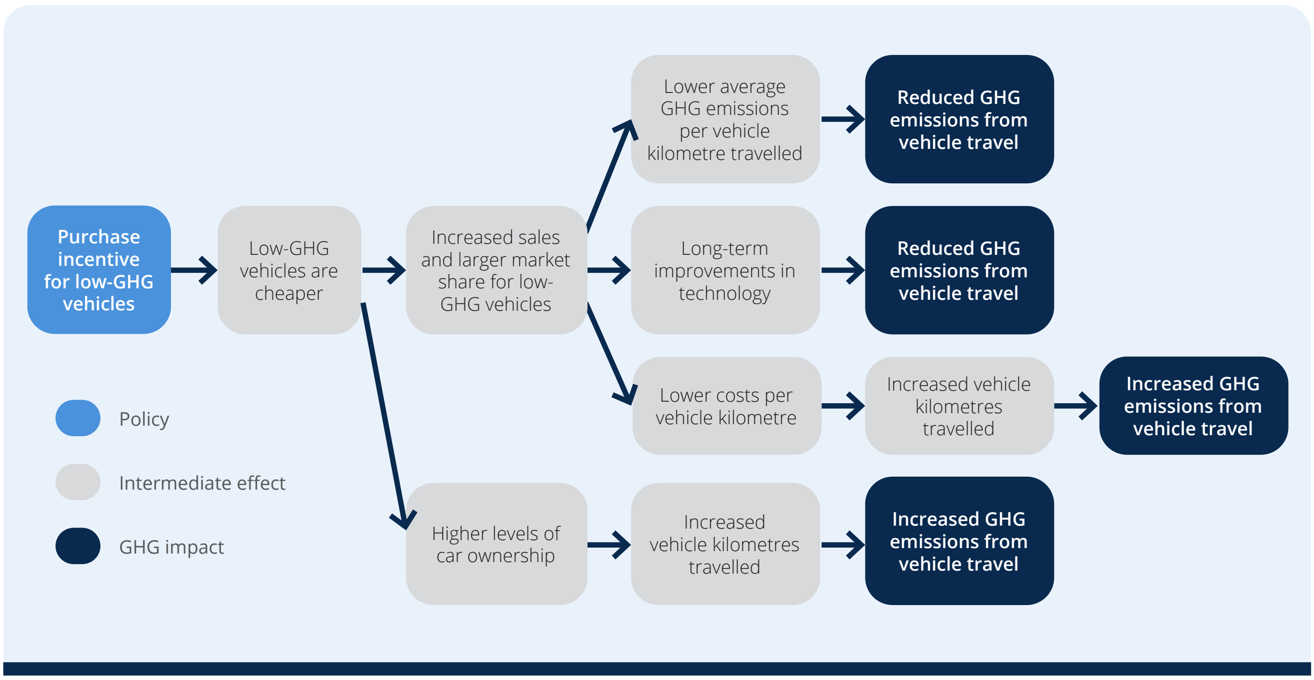
The track record of purchase incentives in expanding the market share of low-GHG vehicles is mixed. Some studies find no effect, while other studies find a measurable impact on GHG emissions. When expressed in terms of the cost per tCO_2e reduced, $100–300 is a typical range.[62] The impact of purchase incentives depends on several factors, summarized 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 smaller impact than policies that target the variable costs of vehicle operation, such as fuel taxes.

10.2.4 Simplified approach for calculating GHG impacts of purchase incentives

Given the range of programme design and other factors that affect the GHG impact of purchase incentives, this methodology recommends a simplified approach to calculating the impact. The simplified approach is based on the aggregate

FIGURE **10.1**

Example causal chain for purchase incentives for low-GHG vehicles



62 Li et al. (2013); Huse and Lucinda (2014).

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 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 electric vehicle market share. As well, the relationship between cost and market share is likely to change as electric vehicle technology matures. Further uncertainty is introduced when applying the method to other technologies, such as hydrogen or CNG. Caution and professional judgment are needed in these circumstances.

Follow the steps below to calculate the GHG impacts of purchase incentives using the simplified approach.

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

- Use equation 10.1.

  Equation 10.1: Estimate average value of the rebate

  $$\textit{Average}\text{ value of the rebate (percentage)} = \frac{\text{Average rebate}}{\text{Average vehicle retail price}}$$

- 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 $50,000, a $2,100 rebate is equal to 4.2%.

  For reductions in ad valorem sales taxes[63] or excise duties, this step is straightforward. The example calculation below shows how to calculate the impact of a reduction in tax from 20% to 15%, which results in a rebate of 4.2%. In this equation, 1.2 refers to a normalized vehicle retail price (i.e. 100% + 20%).

  Example calculation: (0.2 × $50,000 – 0.15 × $50,000) / (1.2 × $50,000) × 100 = 4.2%

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

- Use equation 10.2.

  Equation 10.2: Estimate change in market share of low-GHG vehicles

  $$\text{Market share (percentage point change)} = \text{beta} \times \text{average rebate value [from step 1]} \times \text{market share (percentage point before rebate)}$$

  A default value for elasticity beta of 0.3 may be assumed if no country-specific data are available (derived from aggregate market data and the judgment of the methodology development leads).

  For example, a rebate worth 4.2 percentage points is estimated to translate into a 0.3 × 4.2 = 1.26 percentage point increase in low-GHG market share (e.g. from 0.50% to 0.5 × 1.0126 = 0.5063% of the market).

Step 3: Estimate the per-kilometre emissions reductions from low-GHG vehicles

- Emission factors (CO_2e/km) for both eligible low-GHG vehicles and the existing vehicle fleet can be calculated as discussed in Chapter 7 for baseline emissions. The difference between the baseline scenario and the policy scenario represents the per-kilometre emissions savings from low-GHG vehicles.

Step 4: Calculate GHG impacts

- Use equation 10.3.

  Equation 10.3: Calculate GHG impacts

  $$\text{GHG impact per year} = \text{market share (percentage point change)} \times \text{annual new vehicle sales} \times \text{per-kilometre emissions reductions} \times \text{average annual km per vehicle}$$

For this equation:

- market share is calculated in step 2

- annual new vehicle sales is obtained from official national statistics, and is 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

[63] Taxes according to the value of the vehicle.

- per-kilometre emission reductions are calculated in step 3
- average annual km per vehicle is estimated using national statistics on annual vehicle kilometres and vehicle lifespan. If this information is not available, a default value of 15,000 km per year can be used.[64]

Where a purchase incentive (rebate) for low-GHG vehicles is combined with a (higher) tax for fossil-fuelled vehicles introduced at the same time, both vehicle price changes should be taken into account. A simplified method to calculate the combined GHG impacts of these two pricing measures is to translate the price increase of the fossil-fuelled vehicle into the overall rebate for the low-GHG vehicle (i.e. considering both the price increase for fossil-fuelled vehicles and the price reduction for low-GHG vehicles) and to use the same methodology as described above. Below is an example (adapted from step 1 above):

- The low-GHG vehicle originally costs $50,000, and a rebate of $2,100 is granted (average rebate value = 4.2%).
- The fossil-fuelled vehicle originally costs $25,000, and a vehicle tax of 2% on the vehicle price is introduced at the same time (absolute price increase is 0.02 × $25,000 = $500).
- The increased price of the fossil-fuelled vehicle is translated into the rebate (the total "combined rebate" equals $2,100 + $500 = $2,600).
- The combined rebate value for the low-GHG vehicle equals $2,600 / $50,000 = 5.2%.

This combined rebate value can be used to calculate the change in market share (step 2 above), and the following steps can then be used to calculate the GHG impacts of both pricing policies. Where one measure has been implemented earlier than the other measure, the impacts cannot be combined. For example, if the fossil-fuelled vehicle tax was implemented in 2010 and a rebate for electric vehicles was implemented in 2015, the activity data used to determine the baseline for the assessment of the rebate in 2015 already include the impact of the fossil-fuelled vehicle tax introduced earlier.

[64] Schlömer et al. (2014).

10.2.5 Advanced approach for calculating GHG impacts of purchase incentives

Where more data on vehicle prices, technologies and consumer demand are available, and econometric expertise is also 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 simplified approach presented in Section 10.2.4, 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:

- International Council on Clean Transportation (2014). Feebate Simulation Tool[65]
- DeShazo, J.R., Tamara L. Sheldon and Richard T. Carson (2016). Designing policy incentives for cleaner technologies: lessons from california's plug-in electric vehicle rebate program[66]
- Jin, Lingzhi, Stephanie Searle and Nic Lutsey (2014). *Evaluation of State-Level U.S. Electric Vehicle Incentives*[67]
- Haultfoeuille, Xavier, Isis Durrmeyer and Philippe Février (2016). Distangling sources of vehicle emissions reduction in France: 2003–2008.[68]

Box 10.1 provides a case study from Indonesia.

[65] Available at: www.theicct.org/feebate-simulation-tool.

[66] Available at: www.sciencedirect.com/science/article/abs/pii/S0095069617300049.

[67] Available at: www.theicct.org/evaluation-state-level-us-electric-vehicle-incentives.

[68] Available at: www.tse-fr.eu/articles/disentangling-sources-vehicle-emissions-reduction-france-2003-2008.

BOX **10.1**

Low-cost green cars and electric vehicles in Indonesia

A local team from the Trisakti School of Transport Management[69] assessed two types of purchase incentive policies (as well as conducting an ex-post assessment for removal of subsidies on fossil fuels – see Section 9.2). The assessments show that the methods in the ICAT *Transport Pricing Methodology* can be extended to specific needs that a country or practitioner may have. The report of the Trisakti School of Transportation Management, with detailed information about the assessments conducted in Indonesia, will be published on the ICAT website.[70]

Low-cost green cars: In 2013, the Indonesian Government introduced the "Low-Cost Green Car" (LCGC) programme. The policy is based on tax cuts for more-efficient cars, which increased sales from 45,000 units in 2013 to 850,000 in 2017. The policy was assessed using an ex-post approach based on Section 10.2 of this methodology, as follows:

- country – Indonesia
- base year – 2013; assessment year – 2017
- fuels – gasoline (RON 88, 92, 95, 98, 100): ex-post data from the Indonesian Ministry of Environment and Forestry
- price elasticity – default value
- emission factors – country-specific data from the Ministry of Environment and Forestry, and car manufacturers.

Other than as explained in Section 10.2, the assessment accounts for the fact that, with the cheaper LCGC on the market, it became affordable for more people to own a car. This is presumed to have led to 20% higher car sales compared with the baseline. As a result, emissions are assumed to have been higher with the LCGC programme than they would have been in the baseline (subject to high uncertainties).

Electric vehicles: In August 2019, the Indonesian Government announced that it would accelerate the electric vehicle programme. Production of new cars is aimed to fully shift from conventional to electric by 2040. Since this policy was new at the time of the assessment, little information and data were available. The policy was assessed using an extended ex-ante approach, as follows:

- country – Indonesia
- base year – 2020; assessment year – 2035
- fuels – gasoline (RON 92); electricity
- price elasticity – default value
- emission factors – country-specific data from the Ministry of Environment and Forestry, and average electricity grid emission factor for the different grids operated in Indonesia.

Because of high uncertainties, particularly in the projected electricity grid mix (i.e. coal versus renewables), different scenarios were used to compute the impacts of the policy.

10.3 Road pricing

10.3.1 Overview of road pricing

National and local governments can reduce vehicle travel by charging distance-based fees to use particular roads, or charging fees 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 centre 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,

[69] Institut Transportasi & Logistik (ITL) Trisakti, https://itltrisakti.ac.id.

[70] Sinaga et al. (forthcoming).

and drivers are charged per kilometre driven. Switzerland, for example, charges fees to heavy vehicles based on weight, emissions levels and the distance driven. Annual odometer audits can also be used. Many European countries have implemented distance-based charges for heavy goods 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.

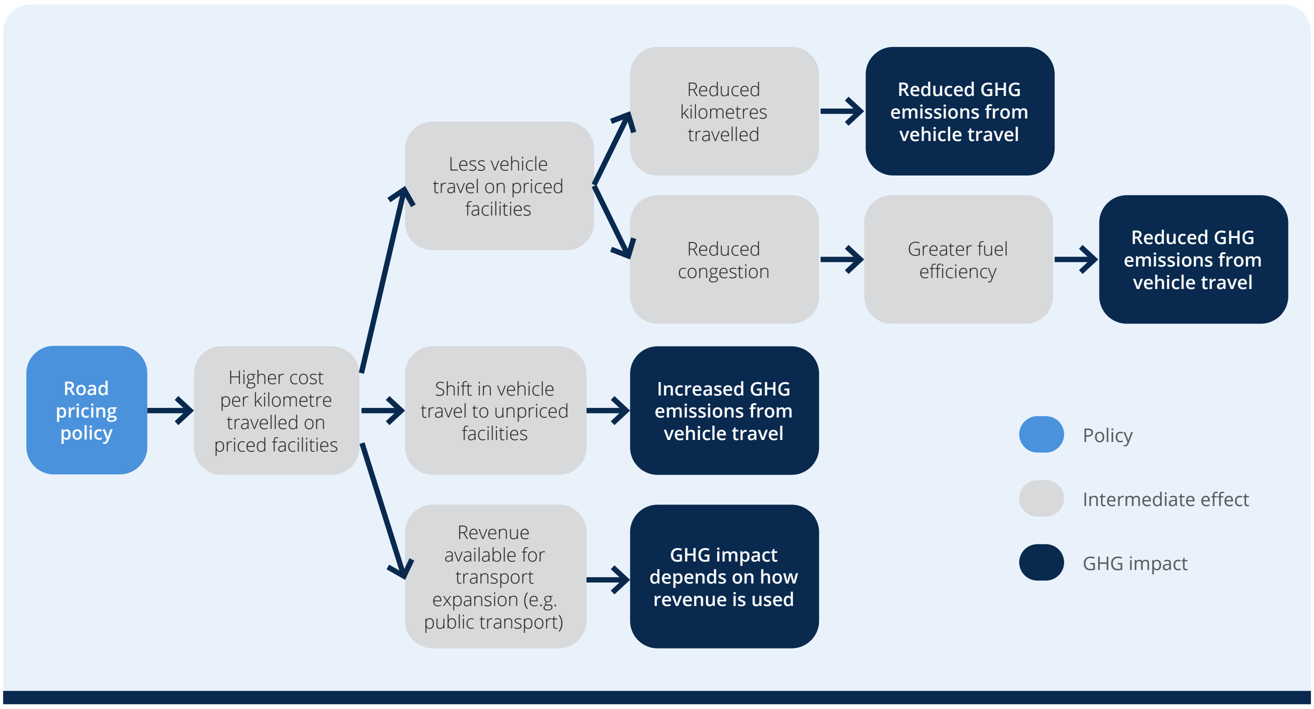
A secondary emissions reduction impact can occur if reductions in congestion allow vehicles to operate more efficiently, through reductions in vehicle idling or operation at inefficiently low speeds.

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-motorized transport facilities; this is likely to reinforce emissions 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 are likely to offset the emissions savings from road pricing. Estimating the additional vehicle travel and emissions is beyond the scope of this methodology. As well, this methodology 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.

FIGURE **10.2**

Example causal chain for road pricing policies



10.3.3 Simplified approach for calculating 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 simplified approach to calculating 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). 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, by applying a percentage reduction to the vehicle travel estimated in step 1. A default reduction of 20% is recommended, based on the experiences of cities that have implemented cordon pricing, where reductions range from 10% to 44%.[71] This assumes that the price is in a similar range to previously implemented programmes in cities such as London (~$14 per day), Stockholm (up to ~$4 per day per entry or exit), and Singapore (up to ~$4.25 per entry or exit). However, project-specific estimates may be available from a travel demand model or similar source.

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

Toll roads and distance-based charges

Step 1: Estimate vehicle travel on the priced facilities (vehicle km/year). For toll roads, annual traffic volume data are required. For distance-based charges, data are required for the subset of the vehicle fleet that is subject to the charges, such as heavy goods 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 using the method in Chapter 8). Use equations 10.4 and 10.5.

[71] GIZ (2015a).

Equation 10.4: Estimate the fractional increase in driving costs

$$\text{Fuel cost per km} = \text{fuel price per litres} \times \text{fuel economy (litres per km)}$$

$$\text{Increase in driving costs} = \text{toll increase (per km)} / (\text{existing toll per km} + \text{fuel cost per km})$$

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 equation 10.5.

Equation 10.5: 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, driving less 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.[72] For example, if the fuel price elasticity is –0.30, the vehicle travel elasticity would be –0.30 × 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 method in Chapter 7.

10.3.4 Advanced approaches for calculating 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,

[72] Goodwin, Dargay and Hanly (2004). The mean fuel consumption elasticity is –0.64, while the vehicle kilometre elasticity is –0.29.

mode share and congestion. For further information, refer to the following:

- Börjesson, Maria, Karin Brundell-Freij and Jonas Eliasson (2014). Not invented here: transferability of congestion charges effects. *Transportation Research Part A: Policy and Practice*, vol. 36, pp. 263–271.

- Eliasson, Jonas, and others (2013). Accuracy of congestion pricing forecasts. *Transportation Research Part A: Policy and Practice*, vol. 52, pp. 34–46.

- GIZ (2015a). *Introduction to Congestion Charging: a Guide for Practitioners in Developing Cities*.[73]

[73] Available at: www.adb.org/publications/introduction-congestion-charging-guide-practitioners-developing-cities.