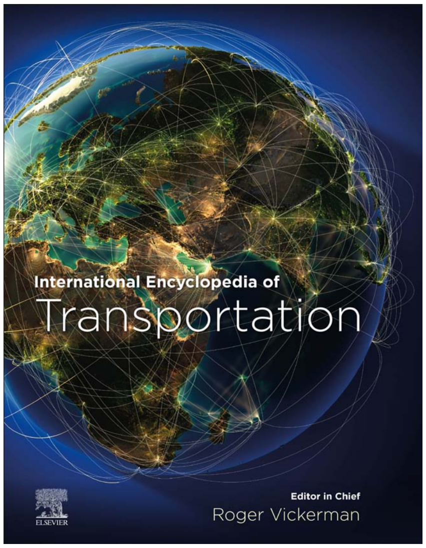

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Policy Instruments to Reduce Carbon Emissions from Road Transport

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Overview

Economic agents typically do not take into account the social cost of their choices or actions, that is, the cost they impose on society. When it comes to transport-related choices this often translates, for instance, into using private rather than public means of transportation, larger rather than smaller vehicles, more rather than less powerful engines.

In the 1920s, Economist Alfred Pigou introduced a concept that became known as Pigouvian tax, which can be seen as an attempt to discipline economic agents. Specifically, if an economic activity generates costs to third parties (external social costs), regulators should introduce a tax equal to the external social cost of such activity, or externality. This arguably simple framework is the starting point of most economic analyses of environmental problems to date.

Determining the level of the tax is, however, a nontrivial task for a number of reasons. First, one has to identify the factors generating external social costs. This could include carbon emissions from transportation, but also local pollution generated by combustion engines and tires, costs of congestion, accidents, noise and visual pollution caused by driving, wear-and-tear of roads, etc. In recent years, it has been identified that, in some jurisdictions, some external costs have been given more importance than others, which may benefit one technology in detriment of another. Concretely, the EU legislation has historically been relatively strict in terms of CO_2 emissions but more lenient with regard to local pollutants, which was documented to benefit diesel in detriment of gasoline vehicles (Miravete et al., 2018) and thus European rather than non-European manufacturers.

Second, one has to correctly quantify each of the earlier externalities. Recent evidence of the manipulation of driving tests led credence that measurement is potentially of first-order importance, especially in diesel vehicles, which led to the recent redesign of test cycles in Europe.

Third, one has to assign monetary values to each of the earlier factors. For instance, local pollution generated today might have long-lasting health effects current research was not yet able to identify.

Fourth, the passing on of taxes onto prices depends on both the competitive structure and on the characteristics of the supply and demand profiles of a particular market. In particular, firms may or may not pass on the cost of a tax to consumers.

Fifth, it assumes that consumers correctly quantify and take into account in their decisions the tax levied on their activities or the products they purchase (Huse and Koptyug, 2018).

Despite the earlier limitations, the Pigouvian framework provides the basic tool kit used by economists and regulators in the analysis of environmental problems, also in the transport sector. If carbon emissions are the only external cost of transport imposed on society, then the Pigouvian tax is efficient (or first-best), in that it imposes on consumers the entire external costs their activity generates to society. In particular, a fuel tax is a Pigouvian tax in this specific case, as introducing it tackles both utilization (kilometers driven) and fuel consumption (how many liters a vehicle requires to drive 1 km) of a driver–vehicle combination.

An additional factor making taxes appealing is that they are cost-effective, in the sense that they satisfy the Least-Cost Theorem, an important result in environmental economics. That is, taxes are able to attain a given environmental target at least cost to the society, which results in an economically efficient allocation of resources. In more concrete terms, if a policy instrument is least cost, then it satisfies the so-called equi-marginal principle, according to which the cost of abating pollution is equalized among all polluters—in particular, economic agents for which abating pollution is cheaper will abate more than those for which abating pollution is more expensive until the cost of abatement of all agents equalize.

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If consumers are not able to identify and/or quantify the extent of the taxation they are subject to, then they will undervalue the fuel tax and overutilize transportation. As a result, this is one channel through which the fuel tax loses its first-best property. Therefore, additional policy instruments are called for, such as standards or vehicle taxes. Although they do not tackle utilization, standards have an impact on the fuel economy (or fuel consumption) of a vehicle, making less efficient vehicles more expensive than their more efficient counterparts. Circulation taxes operate in a similar way, but while standards typically influence only the purchase of new vehicles, circulation taxes are charged yearly and thus affect both the new and the secondhand car market.

The distinction between new and used vehicle markets is crucial since while the former receives considerably more attention, it is only a small (typically single-digit) share of the latter. Thus, one has always to bear in mind the scope of the policy instruments aiming to tackle carbon emissions at the risk of said instruments not having a meaningful impact.

Recent events in the transport sector have brought back attention to local pollutants and shed light on a number of alternative policy instruments tackling pollution in transportation. If local pollutants are not addressed when determining the level of the fuel tax, then alternative policy instruments—especially those targeting diesel vehicles—are called for. These include congestion pricing and driving restrictions, which can occur in various forms.

Finally, considerations about optimal policies have to take into account the political constraints that often prevent a straightforward implementation of those measures. While interventions adopted by governments might not represent the most efficient practice from an economic viewpoint, they might be the only politically feasible solutions.

In what follows, we briefly describe the main policy instruments that can be used to mitigate carbon emissions and their applications.

Fuel Taxes

If the externality policy-makers aim to address is CO_2 emissions, more generally, greenhouse gases, a fuel tax typically charged on a per-liter or gallon basis is a Pigouvian tax on emissions and can thus achieve the first-best outcome in the absence of consumer undervaluation of energy (fuel) costs. Otherwise, to achieve a first-best policy one needs to combine a fuel tax with a standard and a car tax, at least in the case of a representative agent model. For alternative externalities, other instruments would be first-best. For instance, road pricing would address the congestion externality, a per-kilometer tax based on vehicle type might be first-best to address the accident externality and road wear-and-tear (Parry and Small, 2005). In case local pollutants are also considered, the design of policies becomes more complex.

Fuel taxes contribute to the reduction of vehicle CO_2 emissions in two ways: first, they induce drivers to reduce vehicle utilization; second, they push consumers to choose more energy efficient vehicles (Li et al., 2009). The timing of these two effects is different though. While adjustment in kilometers driven can occur within a short time frame from a tax change, the effect on the composition of the vehicle fleet is slower, as generally the increase in driving cost does not justify the immediate replacement of a vehicle. Nevertheless, the presence of two channels of emission reduction rather than only one makes fuel taxes often a better solution than other types of environmental regulation addressing only fuel efficiency, like standards or vehicle taxes.

The way consumers respond to fuel taxes when choosing a vehicle depends also on whether drivers understand correctly the role fuel price has on driving costs—which are also based on fuel economy and kilometer driven. Hence, the question whether a change of 100 in driving costs would be considered equivalent as a change of 100 in vehicle purchase price. Recent evidence on perception of fuel costs and fuel economy shows in general modest to no undervaluation, suggesting that consumers would be able to respond optimally to tax changes.

Compared to fluctuations in fuel prices due to supply-side shocks, fuel taxes have two relevant characteristics. First, any change is often advertised by the media and thus is more salient to consumers. Second, the taxes are more persistent over time. One important implication is that drivers might respond to changes in fuel taxes more strongly than an equivalent changes in pretax fuel price.

While reducing CO_2 emissions, fuel taxes generate considerable revenue. That led to assume the presence of a "double dividend," in which not only fuel taxes would reduce externalities from carbon emissions (first dividend), but they would also allow to reduce other distortionary taxes like the income tax or to fund public goods (second dividend). However, the interaction between the environmental tax and other preexisting distortionary taxes can also exacerbate the efficiency loss caused by the latter. Whether this tax interaction effect dominates or not the effect of the second divided depends on the characteristics of the fiscal system, and has important consequences on the optimal level of the fuel tax—whether lower or higher than the marginal damage linked to CO_2 emissions.

The practical implementation of fuel taxes, and carbon taxes in general, can be subject to significant political constraints. An important reason is that drivers tend to be more aware or attentive of fuel taxes than other vehicle policies (Huse and Koptyug, 2018). Fuel taxes are often also introduced for other reasons, such as to fund infrastructure building and maintenance or as a general source of public funds. Furthermore, specific categories can be more affected than others. The impact over different income groups depends on the availability of automobiles among poorer households, and in general on the share of expenditure on fuel over the total household budget. Drivers living in urban areas can switch more easily to other transportation modes than those living in the countryside. Nevertheless, tax revenue can be used to mitigate those distributional concerns, for instance, through a lump-sum rebate, or through a cut of the income tax marginal rates (Bento et al., 2009). While politically challenging to introduce or change, fuel taxes represent one of the most direct and effective measures to deal with carbon emissions.

Fuel taxes are widespread worldwide, being adopted from EU countries to China, India, the United States, and several emerging economies. Two things are of notice, however, when looking at the levels of fuel taxes worldwide. First, according to OECD statistics for 2018, taxes on gasoline are higher than their diesel counterparts in the vast majority of the countries surveyed, sometimes substantially more so. Second, the value of the fuel tax varies considerably across countries.

Standards

Standards can equivalently be imposed on CO_2 emissions, fuel consumption, or fuel economy, as these are related quantities for a given motor fuel, given the physical relation between a vehicle's CO_2 emissions (measured in, say, gCO_2/km) and its fuel consumption (measured in, say, liters/km).

Standards impose a maximum value on the variable being regulated (a target) and, when binding, act as an implicit, revenue-neutral tax on the variable of interest (Knittel, 2012; Anderson and Sallee, 2016). The inefficiency of standards occurs due to the rebound effect. Additional externalities, such as congestion, will favor fuel tax.

That is, standards incentivize the purchase of more efficient cars but the resulting savings tend to generate an increase in vehicle utilization; dimension standards do not address. Intuitively, this can be shown as follows. Assume the only transport externality is CO_2 emissions, which are measured in grams of CO_2. A fuel tax influences both vehicle utilization (measured in vehicle-kilometers-year, say) and emission rates, whereas a standard affects only the latter. Thus, while the incidence of fuel taxes falls on all determinants of CO_2 emissions, that of standards fall only on part of them, which results in their inefficiency.

Standards apply to new vehicles and might or might not be passed on to consumers by carmakers, partly because of the highly concentrated market structure in the auto industry. Nevertheless, they incentivize the improvement of the regulated characteristic due to the change in relative prices between efficient and inefficient vehicles.

While traditionally standards applied uniformly across products, a number of countries have recently adopted attribute-based standards, according to which a target varies according to some attribute of the vehicle such as its weight or footprint (the rectangular area defined by a vehicle's tires). Typically, larger or heavier vehicles face a laxer standard, which implicitly subsidizes vehicle weight or footprint. Nevertheless, according to the US Energy Information Administration, attribute-based standards have been introduced in most of the major vehicle markets worldwide, including the United States, China, Japan, and Europe.

Vehicle Taxes

A vehicle tax is another policy instrument designed to tackle emissions-related externalities. To clarify matters, it is important to distinguish between a registration tax and a road (or vehicle circulation) tax (also known as vignette in some countries). A registration tax applies only to the first registration of a vehicle. Some prominent adopters are Spain, and South Africa, where the registration tax is set according to the CO_2 emission rate of the vehicle. By contrast, a road tax is to be paid every year by vehicle owners provided their vehicles are circulating (some countries allow vehicles to be periodically de-registered, e.g., during Winter). Thus, while a registration tax has an impact only on new vehicles, a road tax shapes the composition of the whole fleet. This distinction is important since a road tax has been found to impact vehicle retirement decisions and consumer choice in the used vehicle market. In some cases though, an introduction or a change of a road tax applied only to new registrations. That implied that older cars were still subject to previous regulations, often more lenient toward inefficient vehicles.

The vehicle tax is an explicit tax effectively paid by vehicle owners, just as it happens with the fuel tax and in contrast with standards. Typically, the tax is calculated based on vehicle attributes such as weight, fuel type CO_2 emissions, or sales price. This allows regulators some leeway in treating technologies differently. While such characteristics are already correlated with carbon emission rates, some countries based their vehicle tax system in part or fully on the CO_2 emission rate (gCO_2/km) of vehicles.

As it happens with standards, a vehicle tax does not influence utilization, and the marginal cost of driving decreases in fuel economy. For this reason, vehicle taxes are considered less cost-effective and less efficient than fuel taxes in reducing carbon emissions from the transport sector (Cerruti et al., 2019a). Nevertheless, they are often easier to implement from a political point of view, and their use is justified when consumers undervalue fuel costs—and thus fuel taxes—compared to other costs of buying and driving a car. Vehicle taxes directly or indirectly linked to CO_2 emissions have played an important role when it comes to technology adoption (gasoline vs. diesel vehicles) in the European car market, partially explaining the market share commanded by diesel vehicles in Europe (Klier and Linn, 2015; Miravete et al., 2018). Registration or sales taxes are widespread around the world, including Japan, China, India, South Africa, and most European countries.

Rebates and Feebates

Another monetary instruments available to governments to address environmental externalities are subsidies on the adoption of low-emissions vehicles, under the form of a discount on the purchase price (rebate). A rebate can be combined with a vehicle tax to form a feebate (fee + rebate), which often works in a self-financing manner. In practice, feebates are policy instruments used to alter the relative prices of high- and low-energy efficiency products. Fees are charged to vehicles emitting more than a given threshold emissions level (the pivot point), whereas rebates are given to vehicles emitting less than said level (Adamou et al., 2014; Huse and Lucinda, 2014). Because feebates include a sales tax component, the considerations made for vehicle taxes in the previous section largely apply in this context as well. Feebates have been adopted in some European countries, noticeably France and Sweden. Rebates on low-emission vehicles are more widespread worldwide. Both types of policy have historically received substantial attention given the values involved, be it on a per-vehicle basis or in the aggregate.

When introducing rebates for low-emissions vehicles, policy-makers should pay special attention to the impact of free-riding and low pass-through rates. Free-riding occurs when part of the consumers benefiting from the rebate would have chosen a low CO_2 vehicle even without incentives, or when consumers take advantage of political or administrative borders. Such type of behavior decreases the cost effectiveness of environmental programs. In case of low pass-through rate instead, part of a rebate on final vehicle price might not benefit consumers, as car dealers and manufacturers would increase purchase prices accordingly.

Vehicle Scrappage Schemes

Governments can also incentivize the early retirement of old, inefficient, cars. Vehicle scrappage schemes offer a rebate on the purchase of a new energy efficient vehicle if a buyer trades in her old vehicle (Jacobsen and Van Benthem, 2015). After the Great Recession several countries (e.g., the United States, EU, Japan, and China) adopted these programs both as an environmental measure and as a temporary stimulus for the economy. The effectiveness of these incentives as a measure to reduce vehicle carbon emissions is still under debate. The short duration of the scrappage subsidies can exacerbate the free-riding problem. In fact, people might respond to the incentives simply by anticipating by a few months the purchase of a low CO_2 vehicle. If so, the environmental gains from the program will be likely modest compared to its costs.

Information Programs

In order for decarbonization policies to work, proper consumer information is essential. That means providing consumers with information on policy measures and vehicle characteristics, including carbon emissions, presenting such information in a clear and understandable way, and making sure that individuals are able to incorporate the information in their decision-making process. An advantage of information interventions is that they are typically less expensive to implement than other policy instruments. In several countries (e.g., the United States, EU, Chile, Japan, South Korea, and Australia), new cars on sale must display in a visible way the fundamental characteristics of the vehicle, usually contained in an "energy label."

The way information is framed is also important. The CO_2 emissions rate (g/km) is a precise metric, but lacks a reference point for consumer to understand how a car fares in comparison to other vehicles. For this reason, some countries present CO_2 emissions according to letter rating framework (e.g., from A to G). While easier to understand, this simplified design might lead to misinterpretations, in particular when the rating is also based on other vehicle characteristics such as weight (i.e., an "attribute-based label"). Furthermore, information on CO_2 emissions and fuel economy, measured through laboratory testing, is often imprecise. Switching to better testing methodologies, like the recent replacement in the EU of the NEDC with the WLTP test, can attenuate the gap between real-word and measured values.

Although information programs are now widespread, they typically apply only to the new vehicle market. In fact, the use of outdated efficiency ratings in used vehicles, which tend to be upward-biased (e.g., overstating the efficiency of a used vehicle), might provide consumers with wrong information and thus hinder optimal decision-making.

Finally, providing comprehensive information is important not just for vehicle characteristics, but for environmental policies as well. In some instances, people might not be aware, or not have a full understanding, of the incentives in place for switching to low-emission vehicles (Cerruti et al., 2019b). For this reason, the implementation of vehicle taxes and rebates should coexist with appropriate information campaigns to clarify both the existence and the scope of those policies.

Congestion Pricing and Driving Restrictions

The policies considered so far have been implemented at the national or regional level, but they are generally precluded to local governments. Instead, municipalities have applied congestion pricing and restrictions to vehicle circulation in selected areas. In the vast majority of cases the goal of those measures is to reduce traffic congestion or local pollution, but by reducing traffic they might have an effect on carbon emissions as well.

While congestion pricing consists of charging vehicle owners a (potentially time-varying and vehicle-dependent) fee to get access to a certain area, such as the center of a city, driving restrictions only allow a subset of the vehicles to enter such area, sometimes called a low-emission zone. One variant is to restrict vehicles based on occupancy, so only vehicles with at least a number of passengers are granted access to certain lanes, called high-occupancy vehicle (HOV) lanes. While HOV lanes have been introduced mainly in North America, several cities worldwide have implemented either vehicle driving restrictions (e.g., Munich, Mexico City, Quito, and Shanghai) or congestion pricing schemes (e.g., London, Milan, and Singapore).

On the theoretical front, economic efficiency favors congestion pricing over driving restrictions; while the price mechanism inherent in the former allows flexibility and theoretically achieving a least-cost outcome, the latter can be thought of as being akin to licenses, resulting in a number of unintended consequences. Such pricing mechanism affects both distance driven and the vehicle stock, and in some cases might induce people to replace their vehicle earlier with a newer, more efficient vehicle with less driving restrictions.

In some cases, these policies might backfire. For instance, restrictions based on the last digit of the license plate number (odd or even) have prompted households to keep older vehicles longer and in some cases to have two vehicles—one ending with an odd number and another ending with an even number—to circumvent the regulation. While restrictions based on vehicles' emission rates of local pollutants have been shown to be more effective, there might be trade-offs between reducing air pollution and reducing CO_2 emissions. For instance, gasoline cars tend to emit less PM_{10} and NO_x, but more CO_2 than diesel cars.

Distributional effects are another important consideration: as typically driving restrictions and congestion charges are adopted in city centers and residents are granted free access or discounts on the charge, these policies tend to affect more people living in suburbs and commuting to the city. When driving restriction or fees are based on vehicle emission rates, low-income households who keep their older car for longer or who cannot afford to replace their vehicle would be disproportionally affected by the measures.

Mileage (or Utilization) Tax

Although not yet being implemented on a large scale in the context of passenger vehicles, interest in pricing directly vehicle distance driven has grown over the years. In part that is due to the availability of the GPS technology necessary to implement such tax, but in part it is due to concerns that, thanks to the improvements in vehicle energy efficiency, revenues from fuel taxes will decline over time. Because its simplest form does not depend on fuel efficiency, a mileage tax would have an effect on carbon emissions only through the reduction of kilometers driven, but it would not impact vehicle choice. Thus, from a climate policy standpoint it should be considered as a complement of fuel taxes, standards, and vehicle taxes, rather than a substitute (Parry et al., 2007).

Shortcomings of a mileage tax include the fact that it does not address congestion and its distributional effects, since they impose a heavier burden on rural households, who often have less access to alternative means of transportations.

Modal Transport/Public Transport

The provision of public transport services has the potential to affect vehicle use both in terms of intensive margins (how much to drive) and of extensive margins (the decision to buy a car). Moreover, mileage elasticity with respect to fuel taxes or congestion charges is affected by the availability of alternative transportation modes.

Currently, most public transport systems in the world are partially subsidized by local governments, and in Europe a number of towns have considered to introduce—if not already implemented—a zero-fare policy. The rationale for such government subsidies is that the substitution between transportation modes mitigates externalities associated with driving, including carbon emissions. Studies in different countries have indeed shown positive effects of public transport availability in terms of reduction in utilization, congestion, accidents, and air pollution (Anderson, 2014). Thus, it is arguable that positive subsidies toward mass transit are justifiable on efficiency grounds. The optimal subsidy amount likely depends on the existence of other measures aimed to reduce vehicle use, such as congestion charges or dedicated bus lanes.

Afterword

This paper briefly surveys policy instruments currently used in the transport sector. Given how mobility is believed to develop in the coming years, many new exciting questions arise. First is what will be the prevailing technology when it comes to mobility. Although electric mobility currently appears as the leading alternative to internal combustion engines, hydrogen-based alternatives should not be discarded in the long run.

Second, for a given technology to prevail, it requires charging infrastructure which itself might generate new externalities. For instance, in its current form, charging can become a challenge in cities where vehicles are parked on streets, demand for charging can eventually worsen congestion and force regulators and urban planners to rethink how cities are designed and operated.

Third, assuming electric mobility is to prevail, the precise quantification of its carbon footprint is paramount. Currently, batteries are manufactured using minerals extracted under often-unassessed conditions, and whose disposal and recycling calls for increased attention. Moreover, more should be understood about the potential impact of electric mobility on electricity prices as well as the continuing dependence of the carbon footprint of electric vehicles on the source of electricity, which can vary both across regions and even within the day for a given region.

Finally, the choice of policy instruments might be affected by how the business model of the transport sector will develop. For instance, whether vehicles will either be owned, leased, or rented, that is, if transportation will become a service and vehicles will be accessed through a subscription vehicle along the lines of a mobile phone or ISP subscription nowadays, whether batteries will become commodities and will be replaced rather than charged, and the extent to which autonomous driving will be prevalent. All these aspects might have an impact on utilization, vehicle choice, and the speed with which vehicle owners respond to changes in policy instruments and thus on carbon emissions.

Biographies

Cristian Huse is a Professor of Economics at the Department of Economics, University of Oldenburg, Germany, where he holds the chair of Applied Microeconomics. His research interests comprise Applied Econometrics, Applied Microeconomics, Environmental, Energy, and Transport Economics, and Industrial Organization. His research has appeared in scientific journals in Economics and in the Sciences. Recent research examines whether consumers correctly value policy instruments, the choice of energy source in personal transportation, and the effectiveness of environmental policy in the transport sector. He is a graduate of the London School of Economics (PhD in Economics, MSc in Econometrics and Mathematical Economics), the Getulio Vargas Foundation (MA in Economics), and the Federal University of Rio de Janeiro (BA in Economics). His teaching experience includes courses in Econometrics, Environmental Economics, and Industrial Organization, at different levels.

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