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Alberto Gago
Xavier Labandeira
Xiral López-Otero

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Alberto Gago[a,b], Xavier Labandeira[a,b,*], Xiral López-Otero[c]

[a] Rede, Universidade de Vigo, Facultade de CC.EE, Campus As Lagoas s/n, 36310 Vigo, Spain
[b] Economics for Energy, Gran Vía 3, 3E, 36204 Vigo, Spain
[c] Departamento de Teoría Económica y Economía Matemática, Senda del Rey 11, 28040 Madrid, Spain

Abstract

Road transport has traditionally been subject to a number of fuel and vehicle taxes, the purposes being to collect revenue, cover infrastructure costs, or correct externalities (environment and congestion). Yet, over the last few years, several factors have been undermining the operation and effectiveness of such taxes: i) pervasive local pollution and congestion problems that are only indirectly related to type of vehicle and fuel consumption, ii) trend towards a more energy-efficient fleet, reducing the revenue capabilities of the system, and iii) increasing changes in mobility options (car sharing, etc.) In this chapter we suggest a new approach towards transport taxation that is based on both the characteristics of the vehicle and its actual use (time and location). Taxing the real use of a vehicle is now technologically feasible and can more effectively tackle the externalities associated with road transport (including local pollution, climate mitigation and congestion) while maintaining revenue-raising capabilities and providing sizeable tax revenues to different levels of government. Given the difficulties associated with an immediate transition to the new system, the chapter also considers several alternatives for moving from the current tax situation.

*Corresponding author: xavier@uvigo.es

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1. Introduction

Road transport is undergoing the biggest change since the beginning of the 20th century. The scenario for vehicle manufacturing and for vehicle use has been changed substantially by a multitude of factors, including goals to reduce emissions and transition towards low-carbon economies, the impacts of increasing urbanization in today's societies, a new regulatory attitude towards mobility, technological progress in the sector and changes in the patterns of acquisition, possession and use of private vehicles. And, behind these far-reaching technological, social and regulatory changes, others are taking place, and will take place, in every aspect relating to the sector, including fiscal aspects.

Mobility has always been of interest for the tax system, mainly because the purchase, possession and use of vehicles indicate ability to pay, because fuel consumption is inelastic and is on a huge scale, and because tax revenue is high and stable. For decades, tax systems have used a triad of fiscal figures (registration tax, recurring road tax and fuel taxes), which have worked relatively well. But the changes mentioned above are affecting them more and more, even questioning their existence.

In academic circles, stress has been on the revenue brought in by these taxes and their disconnection from the many externalities –global and local pollution, congestion, accidents, etc.– caused by road transport (see Delucchi, 2000; Sansom et al., 2001; Quinet, 2004; Santos, 2005; Maibach et al., 2008; van Essen, 2011; Gago et al., 2014; Korzhenevych et al., 2014; Parry et al., 2014; and Santos, 2017). Their distributive impact has also been questioned (Aasness and Larsen, 2002; EEA, 2011), although the literature shows that taxes on transport are usually less regressive than those on other energy products (Labandeira et al., 2007; Ekins and Speck, 2011; Kosonen, 2012) and may even tend towards progressiveness under certain circumstances (Labeaga et al., 2018; Rausch et al., 2010; Sterner, 2012; Flues and Thomas, 2015).

In regulatory circles, some of these academic arguments have been used to back or draw up proposals. Yet in industrial and commercial areas, changes have been much more intense. Road transport is undergoing far-reaching changes involving new technologies and products, new entrants, different patterns of use and consumption, a constrained market, new regulations on mobility and a real revolution throughout the value chain and in the behavior of all agents (see Capgemini, 2015; Bloomberg, 2016; Kruegen and Johnson, 2016; McKinsey, 2016; BBVA Research, 2017; KPMG, 2017; and ANFAC, 2018).

These changes affect the "comfortable" status that taxes on vehicles and road transport have enjoyed for many decades. Levying taxes on vehicle purchase is being questioned, as are general and specific taxes on consumption. Revenue from them has fallen because of the technological transition that is giving up combustion engines or making them much more efficient; and their efficiency-enhancing properties are being questioned because they are unable to internalize the main externalities in the form of local pollution or congestion. These inefficient taxes, with falling revenue, are unable to maintain their role in the tax system and/or cover the costs of infrastructure, and run the risk of breakdown in domestic markets. They therefore need thorough reform to make up for these failings and to align them with the above-mentioned transformations in their sector and with increasing fiscal and regulatory goals.

In this context, this paper aims to diagnose the current situation and draw up a proposal for reform of automobile taxation to deal with the challenges it faces. For this purpose, we shall first analyze in some detail the current situation of these taxes. In the third section, we shall review the arguments that question their context, considering above all the externalities that are not internalized, the institutional restrictions and the changes in the sector. Based on this analysis and in order to find solutions for the shortcomings detected in the fourth section, we present a proposal for the reform of the existing taxes. We believe that future taxation of vehicles will turn its attention to the substantial externalities, will be characterized by complex fiscal structures with multiple aims, will have a revenue-collection capacity equivalent to or above that of today's taxes on vehicles and fuels, and will base its functioning on advanced telematic technologies that can determine in real time complex tax bases for the use of vehicles of different types in terms of location and time. In view of the complexity and difficulties inherent in immediate adoption of this new system, in the fifth section we study how this transition process and the associated challenges could be defined.

2. Current situation of transport taxation

To date, the application of road transport taxes has largely been based on fiscal reasons (Gago et al., 2014). According to the latest data available on these taxes, they brought in about 5% of tax revenue in both the European Union (EC, 2018) and the USA (USDT, 2017; OECD, 2018) (1.8% and 1.3% of GDP, respectively). The low price elasticity of the main source of revenue, automobile fuels (see Brons, 2008; Labandeira et al, 2017), means that taxes on them have limited effects on consumption and, therefore, on the volume and stability of revenue. In fact, these figures exemplify the so-called optimal taxation on goods and services because, by producing only slight alterations in consumer behavior, they generate public revenue at low efficiency costs (Ramsey, 1927).

The revenue from these taxes has generally been used without any specific assignment, although in some countries it has been used (partially or totally) for funding transport infrastructure. In the USA, the federal tax on fuels finances approximately 90% of the *Highway Trust Fund*, which mainly goes to the construction of highways and other transport projects (Lowry, 2015),[1] while taxes on fuels are also the main source of revenue for states for funding their road networks and other transport infrastructure (Brouwer et al., 2016).

[1] Since 2008, the payment obligations of the *Highway Trust Fund* have exceeded its revenue, requiring the Treasury to make up the difference (Kirk and Mallett, 2018).

The second reason for using taxes on transport is to control externalities. As in other markets, this sector usually adopts decisions in an inefficient framework dominated by the presence of negative external effects of various kinds. This is because there is little consideration of the associated social costs, that is, those resulting from traffic congestion and accidents, those generated by emissions of global (mainly GHG, greenhouse gases) and local pollutants, and noise (Parry et al., 2014).[2] Considering the relevance of such externalities and the size of the associated costs, which may be as much as 5% of GDP in the EU (see Section 3.2), some countries have tried to deal with them by reforming existing transport taxes or introducing new ones.

In this general framework, there are three main categories of road transport taxes that are applied in many countries (Hylén et al., 2013): taxes on vehicles (purchase and recurring taxes), taxes on fuels, and taxes for access to infrastructure and cities. Transport taxation has focused to date on the second of these, which amounts to about 75% of tax revenue in this area (EC, 2018). Since there is a direct relation between the consumption of fuels and emissions of the main GHG, that is, carbon dioxide (CO_2), this is an efficient tool for dealing with the problem of climate change. However, since most of the most important externalities associated with road transport (such as congestion, accidents, local pollution and noise) are not directly related to fuel consumption but vary depending on vehicle type and the place and time of use, such taxes cannot deal with them well. Taxes on vehicles are second in importance and in revenue. Within these taxes a distinction can be made between those that tax purchase of registration through conventional indirect taxes based on the vehicle characteristics (type, power and/or level of emissions), and those that tax traffic by means of direct taxes on vehicle possession, although some applications use more complex designs.

3. Problems and challenges faced by transport taxation

As stated above, we are facing a process of important changes and friction in road transport. The tax implications are obvious. There are doubts about the continued revenue-raising capacity of the existing taxes (without many alternatives for replacing them within existing tax systems), and about their capacity for meeting current and future corrective challenges (without many efficient regulatory alternatives outside this area). We analyze below these challenges and their impact on transport taxation and also give a brief description of some pioneering experiences that might throw some light on options for the future.

[2] These are the most important externalities, but not the only ones, caused by road traffic. For further information, see Delucchi (2000), Quinet (2004), Santos (2005), Maibach et al. (2008), van Essen et al. (2011) or Korzhenevych et al. (2014)

3.1. Technology, behavior and revenue loss

The revenue-raising capacity of fuel taxes, which is crucial for many tax systems and for maintaining road infrastructure in places such as the USA, is decreasing because of the increasing energy efficiency of vehicles and the gradual introduction of hybrid and electric vehicles (McMullen et al., 2010). In the European Union, the energy efficiency of transport increased by 1.2% per year during the period 2000-2013 (Faberi et al., 2015), while fuel consumption of new vehicles fell annually by 3.4% between 2007 and 2015 (ODYSSEE-MURE, 2018) and the use of alternative fuels rose to 7.5% of total energy consumption for road transport in 2014 (Bertoldi et al., 2016). As an illustration, transport taxes have been loosing relevance in both total revenue raised and percentage of GDP (about 17% reduction between 2016 and 2002) in the EU (EC, 2018).[3]

It is very likely that this decreasing trend in conventional taxes on road transport will become more marked in the near future. On the one hand, technological progress will intensify its fiscal effects, which will also be altered by changes in habits and behavior (some of them actually caused by tax systems). The possibility of making up for drops in the tax base of fuel levies by raising the tax rates is limited because of their high levels with regard to other energy products[4] and the difficulty for differentiating, for example, electricity for transport from other uses. It would be easier to update the rates of conventional taxes on vehicle property (purchase and recurring taxes) to adapt to more efficient, cleaner technologies, even though the revenue and regulatory potentials of such taxes are limited.

For manufacturers, the combination of digital progress, environmental arguments, regulatory pressure and energy efficiency arguments is leading to a process of technological innovation that had never been seen before in the sector. Some groundbreaking changes, such as automobile digitalization, connectivity and driverless vehicles, have moved fast over recent years and are already available or soon will be. If we add to this the widespread use of electric vehicles, now that the range and price restrictions have been resolved, we can talk about “the third transport revolution” (Zimmer, 2016), because it involves more than just a change in technology. It is bringing with it a “change in mindset” (Parra, 2016), which is altering the way people see mobility.

Although the media and constant regulatory pressure to achieve environmental goals (local pollution and climate change) are placing electric cars at the head of the transformations, the connected, driverless vehicle is probably more appropriate for identifying the groundbreaking nature of the changes taking place. A scenario of driverless cars amounts to a radical revolution in the mobility model we know, changing the idea of a car as a consumer good, modifying its attributes and reassigning its values. In technical terms, the connected car relates "vehicle to

[3] Similarly, in the US, from 2002 to 2014, the weight of road tax revenue assigned to transport policies dropped significantly in both GDP (by almost 12%) and total revenue (by over 15%) (USDT, 2018; OECD, 2018)

[4] Considering the weighted mean per population in the 22 countries of the EU that belong to the OECD, in 2016 the tax on the prices of gasoline and diesel oil reached 65.1% and el 60.6% respectively, in comparison with 30.1% for domestic electricity and 23% for residential natural gas (OECD/IEA, 2017).

vehicle" and "vehicle to infrastructure" technologies to the development of smart roads and cities (KPMG, 2015). This link will allow for direct communication between cars and traffic lights, road signals and roads with sensors, and even cars with pedestrians' mobile devices, making driving safer and smarter. The driverless car is the next step: using sensors and algorithms, it can cover distances with no driver, and its range will depend on the smart capability of the different roads. So what becomes relevant is no longer the actual transport service but what the driverless car allows during travel, that is, vehicle connectivity and time saved for other purposes.

If the focus moves from the manufacturing process to consumers and their habits/preferences, there will also be very important changes, especially in the way vehicles are used. For the younger generations, the vehicle has largely lost its traditional distinctive nature (as a differential good, with attributes that have value, merit recognition, provide pleasure and assign status), and is becoming almost exclusively a source of accessibility. This means that young consumers are increasingly reluctant to purchase a high-cost durable consumer good that is inactive for much of the time.[5] In the USA, between 1983 and 2014 the percentage of young people holding driving licenses dropped constantly (Sivak and Schoettle, 2016), and between 2001 and 2009 the average number of km-vehicle traveled by drivers aged under 34 dropped by almost one fourth (Davis et al., 2012). This change from ownership to accessibility is very relevant considering that 40% of new cars will be sold to the younger generations (Ivars, 2017). The reasons seem obvious: urban consumers, not only young people increasing feel the weight of private vehicle use in cost and inconvenience (time, fuel, accidents, maintenance, insurance, taxes, parking, etc.), welcome shared use associations and companies offering fleets of cars available for constant use via large digital platforms.

On the one hand, technological change will gradually reduce dirty (fossil-fuel) motorization and, therefore, the revenue from excise taxes on fuels and from pro-environmental registration taxes will be greatly affected. On the other, changes in vehicle ownership and use, together with the incentives to change habits introduced by today's taxes, will lead to additional loss of revenue from the other taxes of the triad: registration and traffic. But unfortunately this drop in revenue does not go together with a solution for the large external costs created by the sector, as discussed below.

3.2. Externalities and taxation in the transport sector

Road transport is responsible for many of the external costs caused by the sector (van Essen, 2011), including both global and local pollution, congestion, accidents and noise. However, the cost of these externalities is not reflected in the market prices of vehicles or fuels and gives rise to inefficient results in the absence of public intervention (Santos et al., 2010). The following are the

[5] Bates and Leibling (2012) consider that in the United Kingdom the average car is parked at home 80% of the time, parked elsewhere 16.5% of the time, and only used actively 3.5% of its useful life.

main externalities associated with road transport. Existing corrective policies are discussed and some guidelines are given for future developments.

3.2.1. Congestion

By congestion we refer to the increase in travel time and in vehicle operating costs resulting from interactions between them on the road, when the volume of vehicles simultaneously using the infrastructure exceeds its maximum capacity. A distinction can be made between two types of congestion, depending on the type of infrastructure: bottleneck congestion and flow congestion (Milne et al., 2000). The former is caused by bottlenecks at certain points (bridges, tunnels, crossroads, etc.), and the latter is caused by traffic that exceeds the transport network capacity. The congestion that is usually observed is really a combination of both. Congestion reduces the speed and reliability of travel and increases the effort needed to drive (Litman, 2013), generating also an increase in fuel consumption and pollution[6]. So the external cost of congestion is the value of the time lost and the increased operating costs imposed by the entry of each additional vehicle into the infrastructure on all users of the road. This cost is not covered by the driver of the vehicle, giving rise to an inefficient result (Newbery, 1990).

The estimates made in the literature indicate that the costs of congestion are the highest of all the external costs associated with road transport (see Table 1). Van Essen et al. (2011) estimate that in 2008 the costs of congestion in the European Union, Norway and Switzerland amounted to 1-2% of GDP, approximately two thirds of which could be attributed to car travel; Schrank et al. (2015) show that the costs of transport congestion in the USA increased from 0.6% of GDP in 1982 to almost 1% of GDP in 2004; BITRE (2015) calculates that congestion costs in the eight main cities of Australia increased by 30% between 2010 and 2015. With regard to future trends, Cerb (2014) calculates that road congestion costs between 2013 and 2030 will grow by 63% in the United Kingdom, 50% in the USA and 31% in France and Germany, whereas BITRE (2015) estimates an increase in Australia of 82% between 2015 and 2030.

These studies point not only to the size of the problem but also to the ineffectiveness of conventional transport taxes for correcting this externality. Fuel taxes increase the cost of travel at any time and in any location, but congestion occurs at certain times and in certain places (usually cities), so they cannot deal properly with this problem (Parry et al., 2007). As an alternative, in some countries, conventional regulations have been used to try to reduce congestion. Some cities (such as Athens, or Mexico City) have prohibited car traffic on certain days depending on their registration plate, but this policy is also inefficient because it leads to an increase in the total number of vehicles on the roads (Davis, 2008, Gallego et al., 2013; Cantillo and Ortúzar, 2014), as it encourages many homes to purchase another vehicle so that they can travel every day (Eskland and Feyzioglu, 1997; de Grange and Troncoso, 2011). Traffic

[6] A vehicle detained in a traffic jam may emit up to three times more than under normal traffic conditions (Goh, 2002).

management measures have also been adopted, such as high-occupancy vehicle lanes, but their success is limited because the time saved does not generally provide sufficient incentives for sharing vehicles, so such lanes are underused (Know and Varaiya, 2008; Dahlgren, 1998). Although an obvious solution for reducing congestion costs is to expand infrastructure, this is not always possible because of the high economic or environmental costs entailed, and anyway such an expansion might just increase traffic (Goodwin, 1996).

In this context, another instrument is needed that adjusts better to externalities, ideally a specific congestion payment that varies depending on the time of day (Parry et al., 2007). The geographical scale, timing, inclusion of environmental objectives, and the legal form chosen (tolls, licenses, charges or taxes) conform a heterogeneous list of growing experiences (see Rye and Ison 2008, Eliasson, 2014 or Endurance, 2015). As we show in the following section, most existing congestion charges are designed to be practical and unsophisticated. They generally treat all vehicles in the same way, in spite of different characteristics and effects, and apply the same fee irrespective of the place or the time. They also usually assign the revenues to the transport sector in order to promote social acceptance, which may lead to efficiency losses (Nash, 2008). Harrington et al. (2001) explain that the low acceptance of congestion charges is still a very important barrier to their use, claiming that such systems are considered mere revenue-collecting measures as there is no alternative for drivers or perception of social improvements.

3.2.2. Air pollution

Automobiles cause pollution at three geographical levels – local, regional and global (Johnstone and Karousakis, 1999). The concentration of most pollutants decreases fast as the distance from their source increases, so environmental damage is essentially local. However, primary pollutants can be converted into others and give rise to environmental damage at regional level. As indicated, vehicles also emit pollutants that contribute to climate change and, therefore, to global environmental problems.

From a fiscal point of view, correcting these costs can be done either through new taxes on emissions or by adapting existing excise taxes on fuels to include environmental damage. At local level, the correction can be also done by adapting vehicle possession and road taxes to the characteristics of vehicles that have the greatest environmental impact (weight, power, age, etc.). However, the environmental damage caused by automobiles depends on many factors such as the style of driving, travel time, the route used, the topography and meteorological conditions, all of which make it difficult to effectively implement such alternatives.

> *Local impacts*

Road transport is one of the main sources of local air pollution, especially in urban areas (DfT, 2015). It is responsible for emitting various pollutants, including particulate matter (PM), nitrogen oxides (NOx), sulfur oxides (SOx), volatile organic compounds (VOC), hydrocarbons (HC) and ozone. In 2015, road transport generated almost 40% of NOx emissions in the EU, 20% of VOC emissions, and about 10% of PM emissions (EEA, 2017). In city centers, traffic is responsible for practically all emissions of VOC, two thirds of NOx emissions and most particles in suspension (Johnstone and Karousakis, 1999). The emission of such pollutants causes different types of damage: to health (of special importance, see EEA, 2015; Mar et al., 2005; Currie and Walker, 2011; Carnovale and Gibson, 2012), ecosystems, infrastructure and economic activities.

Local pollutant emissions mainly depend on the emission standards applied to the vehicle (and therefore related to its age) but also on speed, type of fuel used, combustion technology, load factor, vehicle size, driving style and road location (Maibach et al., 2008). This means that the corrective effectiveness of conventional taxes on vehicles and fuels is low. Knittel and Sandler (2018) show that the use of fuel taxes to correct the externalities of local pollution only covers less than one third of the loss of efficiency caused by the local pollution related to transport and, moreover, such taxes are more regressive than a tax on emissions.

> *Global impacts*

The impact of road transport on climate change is mostly associated with emissions of CO_2 and its contribution to global emissions of GHG is very high (see IPCC, 2013; 2014). Transport emissions amounted to 20% of GHG emissions in the EU in 2016, about 8 points above the level in the early 1990s (EEA, 2018).

Since there is a direct relationship between the consumption of fossil fuels and emissions of CO_2 (Grant et al., 2013), and since climate change is a uniform environmental problem (the damage does not depend on the location of the emission), a tax on fuels could provide this corrective function. As an alternative, some countries have included the level of CO_2 emissions in registration and road taxes to try to change fleet composition towards less polluting vehicles. However, the academic literature indicates that such policies have a limited impact and may even increase emissions.[7]

[7] Ryan et al. (2009) show that during the period 1995-2004 registration taxes did not seem to have a large impact on the intensity of CO_2 emissions from the new EU fleet of cars, and that a 10% increase in road tax for petrol vehicles would only reduce CO_2 emissions per kilometer traveled by the fleet by 0.19% in the short term and 0.88% in the long term. Gerlagh et al. (2018) find that the increased weight of CO_2 emissions in the definition of registration taxes allowed CO_2 emission intensity in new cars to be reduced by 1.3% between 2001 and 2010. D´Haultfoeuille et al. (2014) estimate that the French feebate of 2008, based on the CO_2 emissions of new vehicles, increased car sales by 13% and led to an increase of CO_2 emissions of 1.2% in the short term and 9.2% in the long term.

3.2.3. Accidents

The external social costs of accidents are those that are not covered by insurance policies so depend not only on the level of accidents but also on the existing insurance system. The most important costs of accidents are medical costs, property damage, administrative costs, production losses and what is called risk value, such as a monetary estimation of the suffering caused by the accidents (Korzhenevych et al., 2014). The compensation for risk value is not usually sufficient with private insurance, so that is the main source of external costs of accidents.

The most important factors affecting these costs within road transport are distance traveled, vehicle speed, road type, driver characteristics, traffic speed and volume, time of day (day/night) and interaction with weather conditions. Also important are the level of infrastructure maintenance, the degree to which the infrastructure capacity is used, the separation between lanes and technological developments in vehicles and infrastructure. In this context, a tax on fuel is not a particularly effective tool for internalizing such external costs. A tax on the distance traveled would definitely be a better option, considering also the differences in marginal external costs among drivers, vehicles and regions (Parry et al., 2007).

3.2.4. Noise

Here we include the costs for health and those resulting from the nuisance caused by vehicle noise (Maibach et al., 2008). The main impacts of noise include auditory pain and fatigue, hearing impairment, discomfort, interference with social behavior (road rage and powerlessness), sleep disturbance and all their consequences in the short and long term: cardiovascular effects, hormonal responses and their possible consequences on the human metabolism and on productivity at work and at school (WHO, 2011).

Noise is measured in decibels and the damage it causes is usually estimated using hedonic price models (Parry et al, 2007). Such costs essentially depend on three factors: the density of receptors close to the emission source (indicating the exposed population), the time of day, and existing noise levels (which depend on the volume and mix of traffic and on speed). In road transport, sound comes mainly from the powertrain and the road, both of which depend on the vehicle speed. Other important factors are the type of vehicle, the type of tires, the state of maintenance, and also vehicle age, the gradient of the road, the type of surface and driving behavior (Maibach et al., 2008). So, fuel taxes are not effective for internalizing this externality and alternative systems are needed that take into account the above factors and encourage changes in behavior in the short term (habits) and in the medium term (fleet replacement) (EC, 2011).

3.2.5. Other externalities of transport

There are also other external costs associated with transport that are of less importance but that should also be taken into account when applying corrective transport taxes. They include: road deterioration costs (for repairing the damage caused by traffic and the extra operating costs resulting from such damage (Newbery, 1990); the costs of energy dependence (resulting from the vulnerability of importer countries to price volatility and price shocks, including the transfer of wealth to exporter countries, potential losses of GDP and macroeconomic adjustment costs resulting from adjustments to sudden, large price changes) (Greene and Ahmad, 2005); the costs for nature and the landscape (mainly habitat loss or fragmentation); the costs of land and water pollution; or additional costs in urban areas (e.g. time lost for pedestrians because of separation from the infrastructure, and problems of shortage related to lack of space for cyclists) (Maibach et al., 2008).

Table 1. Main external costs of road transport

Type		Reference	Year	Country	% GDP
Congestion		Delucchi (1997)	1991	USA	0.55-**2.36**
		Winston and Langer (2006)	1996	USA	0.32
		Van Essen et al. (2011)	2008	EU, Norway and Switzerland	1.10-1.80
		Cravioto et al. (2013)	2006	Mexico	1.04-1.05
		BITRE (2015)	2010	Australia	0.94
		BITRE (2015)	2015	Australia	1.13
		Schrank et al. (2015)	1982	USA	0.59
		Schrank et al. (2015)	2014	USA	0.92
		Keller (2018)	2015	Switzerland	**0.29**
Air pollution	**Local**	DMT (2004)	2000	Denmark	**0.15**
		Fisher et al. (2007)	2001	New Zealand	0.24
		Van Essen et al. (2011)	2008	EU, Norway and Switzerland	0.39
		Cravioto et al. (2013)	2006	Mexico	0.61-0.62
		OECD (2014)	2010	OECD	**1.97**
		Guo et al. (2010)	2004	China	0.52
		Guo et al. (2010)	2008	China	0.58
	Global	DMT (2004)	2000	Denmark	**0.11**
		Van Essen et al. (2011)	2008	EU, Norway and Switzerland	0.97
		Cravioto et al. (2013)	2006	Mexico	0.99-**1.00**
		Ivkovic et al. (2018)	2013	Serbia	0.20
	Total	GEA (2018)	2008	Germany	**1.93**
		GEA (2018)	2014	Germany	**1.78**
Accidents		López et al. (2004)	1997	Spain	1.35
		DMT (2004)	2000	Denmark	**0.49**
		Van Essen et al. (2011)	2008	EU, Norway and Switzerland	**1.75**
		Cravioto et al. (2013)	2006	Mexico	1.32-1.34
Noise		DMT (2004)	2000	Denmark	**0.65**
		Van Essen et al. (2011)	2008	EU, Norway and Switzerland	**0.13**
		Cravioto et al. (2013)	2006	Mexico	0.42-0.43

Drawn up by the authors.

Table 1 summarizes the main external costs of road transport based on the existing academic evidence which, as usual, is fairly biased towards the developed world although there are also results for some emerging countries. In each category, it shows damage in relation to GDP, with minimum and maximum values in bold print. Congestion shows the highest values, followed by air pollution (especially at local level) and accidents. When comparisons are possible, the figures show a clear upward trend over time.

3.3. Novelties in transport taxation

The problems and challenges mentioned so far have led to a certain innovation in transport taxation over recent decades. The inclusion of new goals (environmental protection, control of mobility, funding of infrastructure, etc.) has demanded changes in the definition and structure of new taxes. Technical advances in geolocation systems and remote vehicle identification are leading research towards the design of more precise and streamlined fiscal instruments to deal with the problems of congestion and access to urban areas. In this section, we aim to contextualize and summarize the main applications in this area.

The regulatory context in which these new figures are being introduced is fairly biased towards conventional regulatory approaches (command and control). Over recent years, an increasing role is being played by vehicle technology standards, in the form of increasing limits on GHG emissions per distance traveled, but obviously there are many difficulties for dealing with many of the above-mentioned problems. It is therefore not unusual to find prohibitions on access to certain areas, mostly urban areas, for vehicles that do not comply with minimum emission levels (Clean Air, 2015b). A more flexible regulatory alternative is to limit access to such areas by registration plate, sometimes using more sophisticated solutions that also take into account the characteristics of the vehicles entering (Barahona et al., 2018). The fiscal charges for access to certain areas (see section 3.2.1) listed below can be interpreted as an even more sophisticated and flexible approach to limiting access to certain areas and to reducing the heavy external costs (Clean Air, 2015a).

> *Singapore. Electronic pricing system for infrastructure*

In 1975, Singapore became the first country to introduce a congestion tax when it applied a charge on entry into the city center at peak hours. Although the system initially covered only two hours in the morning, it was gradually extended. The impact of the measure was almost immediate and very significant, with a 45% reduction in traffic, a 25% reduction in accidents and an average increase in speed of 90% (EDF, 2006). By the late 1980s, the level of traffic was still 31% lower than in 1975, even though the vehicle pool had increased by 77% (Keong, 2002).

In 1995, the charge was extended to the urban segments of the main expressways (Balmer, 2005) and, as from 1998, it was replaced by an electronic charge that required all vehicles to carry an identification device which, when passing through the fixed ERP positions, automatically generate a fiscal charge. The system allows prices to be changed depending on road type and congestion levels by day and time, which means the mechanism can adjust prices to the optimal level. With this new system, the volume of traffic in restricted areas was reduced by over 15% in just a few years (Goh, 2002). As from 2020, a new system will be introduced to provide drivers with additional services such as real-time traffic information or car park payment (LTA, 2018).

> *Milan: Ecopass and Area C*

At the beginning of the 21st century Milan exceeded EU standards for particulate pollution on an average of 125 days a year (Rotaris et al., 2010), and had thus become one of Europe's most polluted cities. To find a solution, the city introduced the *Ecopass* in 2008 as a trial program for reducing the high levels of PM_{10} and other pollutants. This was a tax for entering the city center from 07.30 to 19.30, which varied depending on the emission standard for the vehicle engine (Anas and Lindsey, 2011). This was replaced as from 2012 with a new program called *Area C*, which covers the same geographical zone but is based on congestion rather than emissions. Among its goals are to reduce traffic, make public transport networks more efficient and attractive, and to improve urban life by lowering the number of accidents, noise and air pollution. Connection with environmental externalities was established indirectly by banning access for the most polluting vehicles and exempting vehicles using alternative fuels from payment.

The initial results of this new tax were remarkable, with a reduction in traffic of one third in the protected area and a 50% drop in access by the most polluting vehicles, and large decreases in accidents (28%) and pollutant emissions (19% in PM10, 31% in NH3, 10% in NOx and 22% in CO_2) (AMAT 2012). Also, during the summer months of 2012 when the tax was suspended by the courts, daily concentrations of VOC increased by 6% and of PM_{10} by 17% (Gibson and Carnovale, 2015).

> *London: Congestion charge*

In 2003, the city of London approved a charge for vehicles entering the city centre, the main aim being to reduce congestion, with an additional element of environmental protection by exempting clean vehicles. The charge was set at an initial daily amount of £5, which rose to £8 in 2005, for entry, movement and parking of vehicles in the selected area from Monday to Friday. Residents have annual passes, which can be reduced substantially if they use clean alternatives, and there are many exemptions for taxis and other vehicles providing public services (Litman, 2011). Application of the tax is based on a system of automatic number plate recognition by cameras located at entry and exit points along the selected urban perimeter (Santos, 2008). Payment can be made by day, week, month or year by any of various systems: machines located within the area, on-line, by post, by telephone or in person in certain stores, service stations and car parks. The system also has a mechanism for charging penalties.

The introduction of this charge was controversial because of its obviously sub-optimal characteristics. It fixes the price per vehicle without taking into account the real number of vehicles entering, nor the type of driving, nor the route taken, nor different peak congestion periods. However, in spite of these limitations, the scheme was a great success. During the first year, congestion in the center dropped by 30%, and by 22% in the second year (TfL, 2005). As a result, traffic speed within the protected area rose by 37% and the number of public transport users by 14%. These improvements, although at lower levels, were maintained in subsequent years (Litman, 2011)[8]. Finally, application of the charge generated large additional revenue, which is exclusively used for improving transport, mainly public and non-motor transport (TfL, 2018).

> *Stockholm: Congestion charge*

Stockholm introduced this tax in 2006 for a six-month trial period, with the idea of subsequently consulting the citizens in a referendum. Even though the consultation had been promoted by those against the measure, more than two thirds of voters approved it and it was therefore introduced permanently as from 2007 (Eliasson et al. 2008). The amount paid depends on the time of day and peak traffic times, and the charge is applied for every trip crossing the designated area, with certain exemptions resulting in 15% of traffic not having to pay (Eliasson, 2014). As in London, the tax is based on a system of cameras that photograph the number plates of cars as they pass through a belt leading to the city center and defined by the points at which the main traffic problems arose in the past. The system records travel and automatically issues the amount to be paid, which is sent to the car owner every month.

The fact that this measure was first applied during a trial period, was then suspended to test its effects and consult the citizens, and finally was reapplied, turned it into an experiment for impact assessment. When it was introduced, it led to an average reduction in traffic of 22% during the trial months, which then jumped up by 15% at the end of the period (with a residual effect probably resulting from consolidation of new driving habits). Subsequently, when it was reintroduced, the trial period traffic levels returned and remained stable in spite of an increase in population and activities (Eliasson, 2014). Congestion, measured in travel time per vehicle, dropped to one third during the morning peak hours and to one half during the evening peak. There were also important effects on traffic-related emissions (drops of 10-14% according to Eliasson et al., 2008).

[8] The alleged fluid traffic was also controversial because, outside the perimeter, congestion increased during the same period, with a bottleneck effect in nearby areas (TfL, 2006).

> *Switzerland: Heavy vehicle charges*

In 2001, after a referendum, Switzerland introduced a tax on motor vehicles and trailers designed for goods transport with a maximum authorized weight in excess of 3.5 tons. The tax is collected via an on-board device which records the distances traveled and the routes used and sends them to the regulator (FCA, 2017). The tax rate depends on the distance traveled, the maximum authorized weight and the vehicle's emissions category. It aims to come near to the costs of heavy traffic that are not covered (Nash, 2003).[9] Revenue is assigned to infrastructure, mainly to fund large-scale actions in the public transport sector (Krebs and Balmer, 2015).

The introduction of this tax had significant impacts on the sector and the environment. Truck traffic dropped by about 5% (Luechinger and Roth, 2016), while the amount of goods carried increased (about 15% from 2001 to 2005), and the number of heavy-transport veahicles crossing the Alps dropped by 15% from 2001 to 2006. This reduction in traffic, together with the increased efficiency of heavy vehicles, led to a reduction in emissions of PM (10%), NOx (14%) and CO_2 (6%), without any significant impacts being observed on employment or consumer prices (Krebs and Balmer, 2015).[10]

> *Netherlands: Tax per kilometer*

This measure is related to a draft European directive of 2005 which, although it did not go ahead, led some states to adapt their tax systems to include correction of environmental damage caused by vehicles. Three factors were behind the Dutch move in this area: i) it was impossible to maintain the status quo of taxation on vehicles in a context of high excise tax on fuel and extensive technological change; ii) serious congestion on roads, with a very high population density and limited possibilities for expanding infrastructure; iii) high maintenance costs of transport infrastructures.

In this context, in 2009 the Dutch government presented a radical proposal to reform taxes on private vehicles, replacing the traditional system with a new tax 'on kilometers'. The rate depended on weight, emissions and car use as well as distance traveled, time of travel and the type of road used (WRA, 2012). Vehicle owners had to fit GPS devices in their cars so that the tax authorities could use their positioning and time data to send them monthly tax bills. The revenue was to be used for investment in transport infrastructure, mainly roads but also railways. The new tax was expected to bring reductions of up to 15% in kilometers traveled (with a 5%

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[9] Including the costs of infrastructure that are not covered by fuel taxes and external costs of heavy traffic (local air pollution, noise and accidents). Neither congestion costs nor those related to GHG are considered.
[10] Not all these impacts can be attributed to the new tax, because other transport policies were also adopted such as higher weight limits per vehicle.

increase in kilometers traveled on public transport), 60% in travel time, 20% in CO_2 emissions from passenger vehicles and 10% in emissions of PM10 and NOx (van Wortel, 2010).

There were, however, several obstacles for implementation. First, entry into force of the reform, planned for 2010, was postponed until 2011 because of social opposition and was then temporarily abandoned. The costs of fitting the location devices in vehicles, privacy and data protection problems and the effect of the tax in terms of equity (as it especially affects people who commute long distances every day), were the main arguments of the opponents (van Wee, 2010). Following the lead of the Dutch, Belgium and Luxembourg started negotiations to install the system together, but they also gave up their projects when the Dutch reform was abandoned.

> *Oregon: Road use tax*

In 2001, faced with a drop in fuel tax revenue (the main source of infrastructure funding), the government of the state of Oregon started to search for new tax alternatives. Of the various options considered, they decided that a payment 'per mile' would be the fairest alternative to fuel tax, so they adopted two pilot programs to test for its applicability (Munnich et al., 2011). In 2015 they adopted OReGO, a voluntary program limited initially to just 5,000 vehicles, in which participants have to fit a device in the vehicle to record the distances traveled. They can choose from various options[11], and the tax applied is 1.7 cents per mile. Fuel taxes, which drivers pay at gas stations, are considered pre-payment and are discounted in settlements of the new tax.

The state aims to extend the system to make it compulsory for all new vehicles by 2026. New federal funds will be used to expand the technological options, improve the management and internal processing and reinforce public acceptance. This initiative has also led other states in the USA, such as California, Washington or Minnesota, to explore similar alternatives by developing pilot programs (Jones and Bock, 2017).

4. Reforming taxation on transport

4.1. Incremental changes in the current system

An initial option for facing the crisis in transport taxation would be to simply avoid its use and increase other taxes to replace the revenue they bring in, using planning or conventional regulations to deal with the externalities associated with transport. In fact, most of the measures being proposed today by cities and governments to deal with transport externalities are

[11] There are various methods for measuring and reporting the distance traveled: the ODOT Account Manager (OAM), a management system approved by the government that does not use location technology; and the Commercial Account Managers (CAM), which are private management systems (Jones and Bock, 2017). When the volunteer chooses a manager, they register on the website giving the vehicle information and the manager sends the device to be fitted in the vehicle. (OReGO, 2018).

regulations or prohibitions of different types. However, although such measures might seem more effective or fairer than pricing instruments, in practice they are substantially less efficient for mitigating transport externalities (Kleit, 2004; Austin and Dinan, 2005; Anderson et al., 2011; Jacobsen, 2013; Anderson and Sallee, 2016; Levinston, 2018)[12] and may also be more regressive (Levinson, 2018).

The second option would be to adjust existing taxes. The economic literature has focused on the analysis of two alternatives for achieving more optimal transport taxation (Parry et al., 2014): the application of a broader and higher fuel tax, and the definition of a package of new corrective taxes that would cover the various externalities with greater accuracy.

Fuel taxes have the advantage of administrative simplicity and feasibility, because they are perfectly consolidated in most tax systems and are easy to understand for taxpayers. However, they entail various difficulties: they cannot cover most transport externalities appropriately; the rates have to be very high to internalize externalities better, especially in the case of diesel (Santos (2017), which would generate substantial socio-economic impacts, and their revenue-collecting capacity would decrease as a result of the above-mentioned energy-efficiency improvements in the sector and a greater relative reaction to tax hikes[13]. In addition, increasing fuel tax rates to mitigate the loss in revenue would have serious distributive impacts because it would raise even higher the fiscal burden on the drivers of less efficient vehicles, especially those using heavy vehicles for working and those who cannot afford a new, more efficient vehicle (Jones and Bock, 2017).

Therefore, an increase in revenue and a decrease in externalities might be achieved more efficiently by a specific package of new taxes. Such a package could include taxes on emissions of local pollutants, on congestion (with zone and time discrimination), and on kilometers traveled as a charge for global pollutants and to cover infrastructure and the cost of accidents. But, in practice, it is difficult to include such "idealized" taxes in the existing tax system. In addition to the rejection generated by most new taxes, it would also be difficult to coordinate and manage such a variety of figures and there might well be distributive objections.

[12] Reducing the use of fuel through taxes is more efficient than through standards or a combination of both because, for any reduction, raising the standard (and reducing the tax) implies that the reduction will come more from the efficiency of the fuel and less from the decrease in the distance traveled, so there will be a smaller reduction in congestion, accidents and local pollution (Anderson et al., 2011). Moreover, standards encourage the owners of used vehicles to postpone the decision to replace them with a new more efficient one by increasing the price of new vehicles, thus reducing the efficiency of the fleet of vehicles (Jacobsen and van Benthem, 2015)

[13] There is growing academic evidence that consumers of fuels for transport react more to tax changes than to price changes because the former last longer and are more salient (Davis and Kilian, 2011; Li et al., 2014; Rivers and Schaufele, 2015; Lawley and Thivierge, 2016; Antweiler and Gulati, 2016; Andersson, 2017). In this context, the drop in fuel consumption might be greater than expected, resulting in an even greater loss of revenue.

4.2. A Comprehensive Automated Tax on Vehicles (CATV)

The above problems suggest that a far-reaching, thorough reform on transport taxation is needed. One initiative with great potential is taxation on vehicle use (McLure, 2009). Such figures can tackle many of the problems associated with today's transport taxation, such as the generation of public revenue, congestion, emissions or infrastructure deterioration (Lindsey, 2010). On the one hand, this alternative has potential for generating more stable revenue than fuel taxes, because drivers cannot reduce their tax burden by driving more efficient vehicles (Langer et al., 2017). On the other, by using tax rates that vary by location and time, the problems of congestion and local contamination could be tackled more effectively, and a tax on the real distance traveled could deal with the other externalities[14].

In this context, our specific proposal for reforming transport taxation is to create a new tax, which we call the Comprehensive Automated Tax on Vehicles (CATV). This new proposal is based on three elements that must be coherently related. On the one hand are the externalities, 95% of which can be included under congestion, local and global pollution, accidents and noise. On the other are vehicle types and the fuels they use, and the location and time of vehicle use, which, overall, are related to many of the externalities generated.

The basic characteristics of the new tax are summarized in Table 2A, with a tax rate that depends on the type of vehicle (grouped by technological category and age) and would have three components: toll for access to a zone and/or for the use of infrastructure, hourly/location tax rates and a levy on the number of kilometers traveled. So, for each category of vehicles, the CATV would comprise tax rates depending on the zone of travel and on the time of travel (possibly with differentiation between different time brackets: 1a, 1b... in zone 1 in Table 1). A tax on the distance traveled (called the off-peak rate in Table 2) would complete the above fiscal structure to cover the costs associated with global pollution, accidents and infrastructure. Note, for example, that, within a specific time bracket, a class 1 vehicle entering urban area 1 might be subject to an entry rate, an hourly payment for congestion/local pollution, and a tax per kilometer traveled to cover the remaining external costs. Table 2B relates the characteristics of each of these fiscal components (type of payment) and the externalities (or infrastructure costs) to be covered.

[14] Moreover, a program taxing vehicle use might help improve safety, by issuing warnings on schools, road works, hazardous conditions or traffic accidents; they might also provide new, added-value services for drivers such as *pay-as-you-drive* insurance (USDT, 2012), automatic payment for parking and tolls, or travel services depending on the location (real-time roadside assistance, identification of nearby points of interest). In addition, the system generates a large amount of anonymous data on travel that could be used to improve transport planning and operation (Sorensen et al., 2012).

Table 2. Characteristics of the CATV

A. Illustration of CATV rates

<table>
<tr><th></th><th>Zone 1 (urban)</th><th>Zone 2</th><th>Zone ... (non-urban)</th></tr>
<tr><td rowspan="2">Vehicle type 1</td><td>Entry toll 1
Hourly rate 1a (...)
Off-peak rate</td><td>Hourly rate 2a (...)
Off-peak rate</td><td rowspan="2">Off-peak rate</td></tr>
<tr><td>Off-peak rate</td><td>Off-peak rate</td></tr>
<tr><td rowspan="2">Vehicle type ...</td><td>Rates
hourly/entrance/off-peak</td><td>Rates
hourly/entrance/off-peak</td><td rowspan="2">Off-peak rate</td></tr>
<tr><td>Off-peak rate</td><td>Off-peak rate</td></tr>
</table>

B. Coverage of externalities per component of the CATV

Vehicle type 1	Payment	Externalities				
		Congestion	**Local pollution/noise**	**Global pollution**	**Accidents**	**Infrastructure**
Entry rate	Euros	X	-	-	-	X
Hourly rate 1a	Euros/hour	X	X	-	-	-
Off-peak rate	Euros/km	-	-	X	X	X

.

Drawn up by the authors

4.3. Transition to the CATV

As explained in the previous section, the CATV would deal better with the externalities associated with road transport and would also have a high potential for bringing in revenue, which would be easily divided among the different administrations depending on the type of externalities corrected (congestion and local pollution for municipal districts, infrastructure for regional and central administrations, etc.). However, there are also problems and difficulties that have to be considered to guarantee the feasibility of the tax.

First, it is important to determine the different categories of vehicle for the CATV and the tax rates applied. For the former, vehicles must be grouped according to the characteristics that are most directly related to the externalities they generate (efficiency, emissions of pollutants, age, etc.). It is essential for each user to know the exact fiscal implications of using their vehicle, but not those of the whole fleet. It is therefore important to complete this system with a registration tax, allowing drivers to take more informed decisions on the future implications of their purchase[15]. Regarding the tax rates, the aim should be to adjust them to the size of the various externalities being taxed, so it will be necessary to use the existing academic evidence (for example, Maibach et al., 2008; Korzhenevych et al., 2014), trying to transfer its results to different realities using more or less sophisticated techniques for transferring values.

Under any circumstances, it is essential for the fiscal structure to be as simple as possible so that users know, at all times, what taxes they are subject to and can adapt their decisions and behavior to minimize the negative externalities they cause. It must be remembered that this is a sub-optimal system in which there must be compromises between gains in efficiency and feasible management (in both grouping the vehicles by class and in the structure and quantification of the various rates).

Second, its technical functioning should be based on mature, well-known, easily-accessed, advanced technology for automatic calculation of the tax. All vehicles should include a permanent, compulsory solution for geolocation, which should not be very different as regards its technical basis and function from those used for the emergency calls system which will be compulsory for all new vehicles in the European Union as from 2018 (EP, 2015). The solution applied in Switzerland (see Section 3.3) could be taken as a reference since it involves a mechanism that cannot be tampered with and is fitted in the vehicle, which records the characteristics of weight and emissions and registers the kilometers traveled and the roads used. With whatever periodicity is determined, these data are sent to the tax administration, which automatically determines the tax base, rates to be applied and amounts to be paid.

In fact, the greatest problem for introducing taxes on vehicle use is social acceptance, which might be so great as to prevent them from being applied[16]. Several aspects of social acceptance have to be considered, starting with its effect in terms of winners/losers: potential losses for businesses established within protected areas, the costs of installing the technological support system, and the possible negative impact in terms of distribution. It seems clear that acceptance of the CATV will be greater if it can be shown that there are significant effects on transport-related externalities and if part of the revenue generated is assigned to funding environmental goals or public transport infrastructure (Beuermann and Santarius, 2006; Gärling and Schuitema, 2007; Sælen and Kallbekken, 2011). Regarding its distributive impact, the literature shows that the regressive impact of taxes on vehicle use is similar to that of fuel tax (Zhang et al., 2009; McMullen et al., 2010; Larsen et al., 2012). Possible compensation for the losers would also help

[15] A registration tax would allow the principle of payment capacity to be maintained as a relevant criterion in fiscal design and would guide purchasers towards vehicles that incur lower negative externalities, thus avoiding contradictions with the functioning of the CATV.

[16] This was the case with the kilometer tax in the Netherlands (see Section 3.3) and the congestion taxes in New York, Edinburgh, Manchester and Birmingham (Hammadou and Papaix, 2014).

increase acceptance, for example, by using revenue to reduce other taxes or for investment in infrastructure and services that would improve the distributive impacts (Levinson, 2010)[17].

In addition, it is necessary to anticipate and counter possible interference with citizens' privacy as it would be mandatory to permanently control the position of all moving vehicles. This would imply access to universal, reserved information which is not only sensitive but also gives rise to the problem of how it is used, processed, stored and/or destroyed. Research in this field is increasingly covering these problems of privacy and data protection, trying to make the accumulation of external information compatible with a certain degree of personal control, reservation and even anonymity.

Finally, it is necessary to consider the problems of jurisdictional assignation of the CATV. Firstly, tax bases and rates have to be adapted to the scope of the externalities in order to avoid overflow effects and loss of efficiency. Secondly, replacing existing taxes with the CATV might affect revenue collection at different levels of government. In this context, the reform proposed should distribute legislative capacity, tax levels and collection among the jurisdictions affected. Given that the externalities have both local and global impacts, the CATV should assign competencies and brackets to every level of government, allowing them to participate by means of different quotas. The CATV could be constrained to keeping at least pre-reform revenue which, depending on the jurisdictional distribution of taxes, might alter the above allocation of rates and bases. In sum, it will be necessary to combine these objectives in order to achieve good territorial assignation of the CATV.

It seems clear that an immediate move to the CATV would be very complex and costly, so it should be done gradually, in both intensity and time, in order to reduce negative impacts and achieve better adaptation. We therefore propose that introduction of the CATV should take place in two phases. During the first transition phase, the obligation would be established to install a device with GPS identification technology or the equivalent in new vehicles, with a period for gradual adoption of such mechanisms in all vehicles. During this phase, conventional transport taxes should be increased to promote the renovation of the fleet. Also, experimental pilot projects introducing the CATV would be carried out, from which practical lessons could be learnt towards final implementation. The end of this transition period, by when all or a large proportion of the fleet would carry the device and its technological and environmental obsolescence would be limited, and after analyzing the result of the pilot project, would lead to the full introduction of the CATV to substitute most existing taxes levied on road transport.

[17] It should also be remembered that covering income inequality by taxation and welfare systems is more effective and efficient than subsidizing goods, as allowing prices to be lower than the social cost is equivalent to a subsidy (Eliasson, 2016).

5. Conclusions

Taxation on automobiles, a traditional source of sizeable and stable revenue in much of the world, is today facing challenges that indicate that a radical transformation is needed if the system is to continue meeting its two main objectives: to bring in revenue and to correct externalities. On the one hand, technological progress and changing consumer habits are leading to a drop, which will increase over coming decades, in the tax revenue associated with traditional transport taxes. On the other hand, there is both increasing concern about the effects of the externalities associated with transport and a worsening of these effects. We have observed in this study, however, that conventional transport taxation cannot cover these externalities as required.

This chapter proposes a reform of vehicle taxation that would allow existing challenges to be met, guaranteeing the feasibility of taxation on vehicles in the 21st century. This reform would basically involve replacing traditional transport taxes with a new tax, called CATV, that can internalize the externalities associated with vehicle use by means of tax rates that vary in accordance with the type of vehicle, its zonal and hourly use, and distance traveled. Application of the tax would be based on location technologies that already exist, which would make it possible to automatically calculate the tax and would guarantee confidentiality for the information supplied.

An immediate transition to this new system would be complex and probably costly, and would face problems of jurisdictional assignation and social acceptance. The move from the current taxation system for vehicles to levies on use would therefore have to take place gradually. The first phase would focus on the installation of geolocation devices in new vehicles and on developing pilot projects, as well as a considerable rise in conventional transport taxation to promote renovation of the vehicle fleet. After this phase, it would then be possible to introduce the CATV with greater guarantees, substituting existing taxes and promoting a much better internalization of external costs while keeping revenue capacities.

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