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Beneficial Tax Incentives**
A Literature Review

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Aspects of environmentally beneficial tax incentives – a literature review¹⁾

Angela Köppl, Margit Schratzenstaller

Abstract

While environmental taxes aim at making environmentally harmful behaviour more costly, the opposite is true for environmentally beneficial tax incentives. Tax incentives imply foregone public revenues to favour less polluting consumption and investment activities in order to achieve environmental policy goals. While there is a large body of theoretical literature on environmental taxes and emissions trading, the theoretical literature on environmentally beneficial tax incentives (as well as direct subsidies) is rather slim. Most of the literature in the field of beneficial tax incentives consists of empirical case studies on concrete tax incentives that have been introduced in individual countries. The paper provides a review of theoretical and empirical literature addressing the effects of environmentally beneficial tax incentives. Hereby, the review of empirical evidence on the impact of specific tax incentives to reduce GHG emissions focuses on tax incentives in the transport sector and particularly on those attached to vehicle taxation aiming at supporting the decarbonisation of the car fleet. We also summarise the sparse empirical evidence on tax incentives intended to support the use of public transport, green R&D, and energy efficiency.

Keywords: carbon taxation, environmental taxation, price-based instruments, tax incentives, climate policy

JEL-Codes: H23, Q54, Q58

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Introduction

This paper provides a review of theoretical and empirical literature addressing the effects of environmentally beneficial tax incentives.

1. Conceptual aspects of environmentally beneficial tax incentives

While environmental taxes aim at making environmentally harmful behaviour more costly, the opposite is true for environmentally beneficial tax incentives. Tax incentives imply foregone public revenues to favour less polluting consumption and investment activities in order to achieve environmental policy goals. While there is a large body of theoretical literature on environmental taxes (see e.g. Köppl and Schratzenstaller 2021 for an overview) and emissions trading (see e.g. Healy et al. 2015, Tang et al. 2020), the theoretical literature on environmentally beneficial tax incentives (as well as direct subsidies) is rather slim. Most of the literature in the field of beneficial tax incentives consists of empirical case studies on concrete tax incentives that have been implemented in individual countries.

Beneficial tax incentives are mostly discussed in the context of instrument choice for environmental policy (e.g. Goulder and Parry 2008). In many cases they are not discussed as a stand-alone instrument, but rather in the context of a combination of policy instruments in environmental policy. Kosonen and Nicodème (2009) point out that under certain market imperfections, relying on a combination of instruments and applying e.g. also beneficial tax incentives may be less costly than relying on one pricing instrument alone. Potential synergies achieved through a broad instrument mix are highlighted by Grubb (2014), Mercure et al. (2014), Rafaty et al. (2020) and Peñasco et al. (2021).

The OECD has taken up the topic of environmental subsidies several times and has provided a comprehensive discussion of various conceptual aspects of beneficial tax incentives (e.g. Greene and Braathen 2014 or Duval 2008). An environmental tax relief or tax incentive is a government measure that aims at steering expenditure of individuals and businesses away from environmental "bads" towards environmental "goods" by reducing the amount of tax that they have to pay (OECD 2011b). Tax incentives thus imply that the government foregoes tax revenues to favour less polluting consumption and investment in order to achieve environmental policy goals and thus address positive externalities²⁾. In other words, a beneficial tax incentive encourages behaviour that generates additional social benefits which would not have been created without the subsidy.

In its database documentation for the PINE³⁾ database the OECD defines environmentally motivated subsidies as follows:

²⁾ The argument of positive externalities is also of relevance in connection with R&D spending, since the revenues from new technologies, despite patent protection, do not entirely flow to the original investor, R&D expenditures result in a level below the socially desirable level. For an overview see e.g. Hall and Van Reenen (2000).

³⁾ Policy Instruments for the Environment database. For the definition of environmentally motivated subsidies see http://www.oecd.org/environment/tools-evaluation/PINE_Metadata_Definitions_2016.pdf.

"A subsidy is defined as environmentally motivated if it reduces directly or indirectly the use of something that has a proven, specific negative impact on the environment. ... environmentally motivated subsidies consisting of payments from government to producers, or of preferential tax treatments with the objective of influencing the level of production, the price, or the remuneration of the factors of production. Environmentally motivated subsidies could take the form of a VAT exemption or another favourable tax treatment, such as the VAT exemption for electrical vehicles. ...Other types of environmentally motivated subsidies would be grants or loans totally or partially financing projects or activities aimed at protecting or restoring the environment, nature preservation or conservation of environmental heritage.".

This definition already gives an indication of the many ways in which environmentally relevant subsidies can be designed. However, it should be noted that the broader the policy objective and the more heterogeneous the sectors addressed, the more difficult it is to design a tax incentive suited for all.

In general, there are several aspects that should be considered in the decision whether to implement tax incentives and how to design them. The following table is essentially based on Greene and Braathen (2014) and summarises the aspects and arguments related to environmentally beneficial tax incentives discussed there.

Compared to the discussion and theory on price incentives (taxes and emission rights), the literature on recommendations for the use of tax incentives which can be derived from a theoretical perspective is much less extensive. Greene and Braathen (2014) stand out with their paper and the clear discussion of the most important arguments. In contrast to environmental and carbon taxes, beneficial tax incentives are often discussed as a complementary instrument in order to tackle specific environmental problems. Kosonen (2012) gives two examples: firstly, information costs that cannot be tackled e.g. by an environmental tax alone or emissions that are difficult to measure or difficult to assign to individual emitters. Secondly, market barriers which prevail in addition to negative external environmental effects. The argument is that a combination of instruments, such as a tax in combination with a tax relief, can achieve a policy objective at lower costs than a stand-alone tax.

In general, which policy instrument or which instrument mix is ultimately chosen should be based on a thorough analysis of different aspects, such as tax policy arguments, or how a specific policy objective can be achieved at the lowest cost and with the highest probability of achieving a stated goal. Finally, aspects of political acceptance also play a role. In particular, a combination of a tax relief and an environmental tax can increase the acceptance of the latter and prepare the ground for its implementation.

Table 1 Overview of findings on beneficial tax incentives

Tax incentives....	Explanation
do not internalise negative externalities into prices	Compared to environmental taxes that price negative externalities, tax incentives do not address the polluter pays principle.
can address true positive externalities	<p>Tax incentives subsidise positive externalities. They encourage behaviour that generates additional social benefits which would not have been achieved without the subsidy. This applies in particular to R&D in general - not green technologies specifically - where positive innovation spill overs occur.</p> <p>Positive externalities can be relevant when the beneficial tax incentive contributes to reduce the risk for early adopters. Early adopters provide "learning by doing and use" information that can translate into lower costs for late adopters.</p>
often attempt to "pick winners"	Since it is difficult to benefit all environmentally beneficial alternatives to the harmful activity, tax subsidies inevitably involve "picking winners", which may overrule other good alternatives. For example, a subsidy for low-emission vehicles does not provide any incentive for commuters to consider alternative forms of transportation such as public transport or cycling. The problem of "picking winners" can be mitigated if the tax exemption is linked to results or performance measures rather than inputs or specific technologies used. It can also lead to a rebound effect (see below under 'increased pollution').
are not well suited to address certain market failures	Preferential tax benefits are not appropriate for certain market failures, such as missing information on environmentally favourable alternatives, limited access to credit or a principal agent problem between landlords and tenants. Preferential tax incentives in such cases are likely to be costlier than other regulations, e.g. rental laws, information campaigns.
can lead to increased pollution	Tax reductions can lead to a rebound effect, as they make certain activities cheaper and thus possibly provide an incentive to increase the level of activity which then increases environmental harm. Support for more energy-efficient equipment can have a rebound effect if the new equipment is larger and thus offsets part of the efficiency gain.
require clear objective standards	The administrative costs of beneficial tax incentives depend on the implementation of clear and simple criteria on the eligibility for the preferential tax.
can cause windfall gains or "free riding"	Windfall profits are not specific to environmentally motivated beneficial tax treatment but apply to other government support as well. If beneficiaries would have undertaken the environmentally beneficial activity anyway costs are shifted from the private sector to the government sector. The more ambitious the standards and criteria for eligibility, the lower the probability of "free riders". Tightening the standards and eligibility over time can partly incentivise innovation.
require costly funding	Tax relief entails fiscal costs, as the lost tax revenue would have to be compensated by other sources of revenue. These costs should be made clear when designing tax relief schemes.

Tax incentives....	Explanation
are often less scrutinised than alternative policy instruments	Beneficial tax preferences, as tax preferences in general, are often perceived as permanent and often lack a regular evaluation. This calls for a close examination of whether this is the best policy instrument before being introduced.
may not be helpful to non-taxable entities	Only those will benefit from a beneficial tax preference who are liable to pay taxes. E.g. if the measure is aimed at reducing income tax, low incomes households that do not pay taxes may be excluded. In this case, the instrument lacks effectiveness.
may result in unwanted distributional effects	Especially picking winners as well as the exclusion of non-taxable entities can lead to non-desired distributional effects. Undesirable distributional impacts can also occur between higher-income and lower-income households if lower-income households do not have sufficient financial resources despite support. Also, the design of a funding instrument has an impact on distribution. A tax allowance, for example, favours higher-income households more than lower-income ones
need to be coordinated with other domestic policies	Beneficial tax preferences are often seen as complementary measures and thus need to be embedded in an overall policy package.

Source: Greene and Braathen (2014).

2. Empirical evidence on the effects of tax incentives

2.1 General aspects of environmentally beneficial tax incentives

Tax incentives to support environmentally friendly or to discourage environmentally harmful behaviour are much more diverse across countries than environmental taxes are. This regards the supported economic activity (consumption versus investment), the concrete environmentally relevant activity they try to influence (e.g., purchase and use of cars, use of public transport, use of biofuels and renewable energy, investment and research in energy efficiency and clean technologies), the economic actors they benefit (private households versus firms), the concrete tax they are built in (direct taxes, i.e. personal and corporate income tax, versus indirect taxes, i.e. consumption taxes), as well as their concrete design (direct taxes: reduced tax rates, tax allowances reducing taxable income versus tax credits reducing tax liability; indirect taxes: reduced tax rates, total or partial exemption of tax base). Tax incentives are but one – and probably the least important – instrument to further environmentally beneficial behaviour and decisions. The existing theoretical and empirical literature suggests that fiscal incentives, in particular grants, direct subsidies, and preferential loans, are more prevalent than tax incentives.

Compared to the large body of empirical evidence on the effects of environmental taxes in general and taxes addressing greenhouse gas emissions in particular, the number of empirical analyses of environmentally beneficial tax incentives is rather limited. Many of these analyses evaluate individual measures in single countries (regarding the EU, these analyses with very few exceptions focus on "old" Member States), while cross-country comparative analyses are less common. A part of these studies analyse a given tax incentive isolatedly, i.e. without evaluating it against alternative policy instruments and thus without addressing the question what would have been the benefits of alternative policy measures to reduce emissions. However, there is a growing body of comparative evaluations of alternative policy interventions. The bulk of analyses consists of ex-post evaluations, there are only few ex-ante simulations of hypothetical scenarios.

Before presenting empirical evidence on specific tax incentives, we briefly provide an overview over some general, structural aspects concerning the effects of environmental tax incentives that are also reflected in Table 1.

Firstly, regarding the design of tax incentives to promote some specific desired environmentally beneficial behaviour, empirical evidence suggests that tax incentives must be salient to change behaviour (Chetty et al. 2009, Finkelstein 2009, Busse et al. 2013). Deshazo et al. (2017) show that tax rebates and exemptions granted at the time of sale are more effective than complex income tax incentives: as the latter have to be applied for by consumers and bring about financial relief with a delay only, which therefore may be undervalued due to consumer myopia (Allcott and Wozny 2014). For example, Gallagher and Muehlegger (2011) show for the US that exempting hybrid electric vehicles from the sales tax may lead to an increase of sales by 45%, while income tax credits of a similar magnitude increase sales by 3% to 5% only. Similarly, a study of government incentives policies in US states to support the adoption of hybrid-electric vehicles by Diamond (2009) suggests that incentives providing payments upfront are

most effective. Accordingly, with specific regard to the design of vehicle taxes, there is growing empirical evidence that car purchase taxes as well as feebates (i.e. a combination of tax rebate for the purchase of a low-emission car and a fee for the purchase of a high-emission car), acting as upfront incentives, are more effective (Kok 2015, Brand et al. 2013).

Secondly, tax incentives are often viewed as problematic from a distributional point of view. Zachmann et al. (2018) generally assume that subsidies for low-carbon technology granted to private households (e.g. for vehicles, building insulation, or roof-top solar) can be rather regressive, as only higher income households can afford to invest in low-carbon durables. The scarce available empirical evidence suggests that the regressive effects of carbon pricing policies are less pronounced than those of subsidies. According to Borenstein and Davis (2016), the US clean energy tax credits have less favourable distributional effects than carbon pricing.

A third, related aspect is free-riding and the question of additionality, i.e. whether a tax incentive is granted for an activity that would have taken place anyway. The more prevalent free-riding is, the less cost-effective a given tax incentive is. Generally, tax incentives are often found to be little cost effective, which is why some authors (e.g. Metcalf 2008) argue that carbon pricing should be preferred to tax incentives. Tax incentives are generally perceived as being prone to free-rider aspects. Empirical evidence for free-riding is found particularly regarding tax incentives for the purchase of electric vehicles: e.g. by Chandra et al. (2010) for tax rebates granted in Canadian provinces for hybrid electric vehicles, by Huse and Lucinda (2014) for the Swedish "Green Car Rebate", or by Sun et al. (2018) for the sales tax reduction for electric vehicles. Low cost-effectiveness of tax rebates is also suggested by Yan (2018) who studies tax incentives for electric vehicles in 28 European countries from 2012 to 2014. For the case of California's tax rebate program for electric vehicles, Deshazo et al. (2017) demonstrate that a progressive design of tax rebates which decreases the size of tax credits with income may increase cost effectiveness per additional vehicle purchased, as free-riding decreases with decreasing income. Metcalf (2008) deems US energy-related tax incentives less cost-effective compared to a carbon pricing scheme. Similarly, Arigoni Ortiz et al. (2009) compare tax incentives and subsidies against energy tax options to promote the production and consumption of energy-efficient appliances in different European countries (Denmark, Italy, France, and Poland) and find that generally the energy tax in most cases is more cost-effective. According to Ruijs and Vollebergh (2013), an energy investment tax allowance granted to firms in the Netherlands was found to be associated with large free-rider effects.

Finally, there is some empirical evidence supporting the theoretical consideration that "package solutions" combining several climate policies in general and carbon pricing and tax incentives in particular (Baranzini et al. 2017) may be more effective than single measures. For example, Beresteanu und Li (2011) show that a combination of fuel tax increases and tax incentives stimulates the adoption of electric vehicles most effectively.

2.2 Specific tax incentives

The availability of empirical evidence on the effects of environmentally beneficial tax incentives varies greatly across the various kinds of tax incentives and the activities they intend to promote. While there is a growing body of empirical literature on the effects of tax incentives

aiming at supporting the de-carbonisation of the transport sector, and here with a focus on the adoption of low-emission cars, there is practically no empirical research on the effects of tax incentives for "green" research and development and for the implementation of measures to further energy efficiency and the adoption of renewables. Obviously this reflects the fact that many countries have introduced rather similar (albeit differing with regard to the detailed designs) tax incentives to further the adoption of low-emission vehicles via the conventional tax measures applied with regard to individual transport: concretely, many EU Member States have introduced a carbon emission element in vehicle taxes (registration tax, annual circulation tax) as well as company car taxation; and there is some experience with feebate and car scrapping schemes⁴⁾ as well as specific tax incentives to purchase (hybrid) electric vehicles. The group of Member States granting tax incentives for the use of public transport is considerably smaller, as is naturally the body of respective empirical evidence. The following review of empirical evidence on the impact of specific tax incentives to reduce GHG emissions therefore focuses on tax incentives in the transport sector and particularly on those attached to vehicle taxation aiming at supporting the decarbonisation of the car fleet.

2.2.1 Tax incentives in the transport sector

Incentives for the adoption of low-emission cars, in addition to fuel and vehicle taxes⁵⁾, are generally justified by consumer short-sightedness regarding future fuel savings through low-emission cars. Such incentives can be built in into various vehicle-related taxes, and accordingly they are rather heterogeneous across countries. They range from sales tax reductions (granted e.g. by China during the financial and economic crisis one decade ago, Sun et al. 2018) and exemptions in VAT over reductions/exemptions from car purchase taxes and annual registration taxes to other vehicle-related tax incentives granted, for example, via company car taxation. Also, feebates combining a malus for high-emission and a bonus for low-emission cars have been gaining in popularity recently. The existing empirical evidence allows only limited conclusions which measures are particularly effective, as comparisons of the effects across individual measures are hardly possible. Moreover, most empirical analyses focus on one or at most two impact dimensions (with a particular focus on cost effectiveness, environmental effectiveness, and free-rider effects), so that trade-offs can be detected to a very limited degree only. In addition, certain impact dimensions, in particular distributional effects, are neglected in most evaluations. Most empirical studies focus on individual measures in individual countries, therefore based on existing empirical evidence neither cross-country comparisons nor comparing different designs of tax incentives aiming at the adoption of low-emission cars are possible. Finally, there is almost no empirical evidence for the "new" EU Member States having acceded the EU beginning with 2004.

⁴⁾ Car scrapping schemes were introduced in many cases as a stimulus measure rather than as a primarily environmentally motivated measure.

⁵⁾ For an overview over vehicle taxation and their empirical effects see Köppl and Schratzenstaller (2021).

2.2.1.1 Tax incentives for the purchase of low emission cars

Tax incentives for the purchase of low emission cars can take various forms. Specifically, two kinds of such tax incentives have gained in popularity in Europe as well as in other industrialised countries worldwide: tax incentives for the purchase of (hybrid) electric vehicles, and carbon-based car purchase taxes.

Experience from several countries shows that tax incentives can be an effective measure to incentivise sales of greener vehicles. Tax incentives immediately granted at the time of purchase and thus salient for consumer are found to be particularly effective. Responding to the recession during the crisis in 2008/09, China halved the sales tax on small engine size vehicles, which according to Sun et al. (2018) increased overall car sales, shifted demand from ineligible to eligible cars, and reduced carbon emissions. According to Gallagher and Muehlegger (2011), waiving sales taxes may lead to an increase of hybrid electric vehicle sales by 45% in the US and is thus far more effective than income tax credits of a similar size. For Canadian provinces, Chandra et al. (2010) show that tax rebates for hybrid electric vehicles support their adoption, and also in Sweden the market share of low-emission vehicles was increased by the Swedish "Green Car Rebate" (Huse and Lucinda 2014). Similarly, a survey by Ystmark Bjerkan and Norbech (2016) finds that exemptions from car purchase tax and VAT, resulting in upfront price reductions, are critical incentives for more than 80% of respondents. This survey is interesting also because it identifies different user groups (differentiated by gender, age, and education) responding to different incentive groups, whereby a substantial share of users rather responds to exemptions from operating costs (e.g. road tolling) than from upfront costs. Analysing the factors influencing electric vehicle sales on a regional and municipal level in Norway, Mersky et al. (2016) find no significant impact of toll exemptions, while access to battery electric vehicles charging infrastructure, proximity to major cities, and regional incomes are important determinants of electric vehicle adoption.

Several studies research the effectiveness of tax incentives for the adoption of (hybrid) electric vehicles. Yan (2018) evaluates the effects of tax incentives for electric vehicles, which differ across vehicles, countries and over years, by analysing 10 pairs of battery electric vehicles and internal combustion engine vehicle counterparts across 28 European countries from 2012 to 2014. He finds that large battery electric vehicles benefit more from tax incentives compared to small ones. Moreover, the impact of tax incentives on hybrid electric vehicle sales is higher than for sales of battery electric vehicles. On average, a 10% increase of the total tax incentive raises the share of battery electric vehicles by around 3%. The author concludes that the cost effectiveness of tax incentives as instrument to decrease carbon emissions is rather low. Plötz et al. (2016) study the effectiveness of various instruments aiming at the increase of electric vehicle sales for selected European countries and US federal states and find that tax incentives can play a positive role. However, their results do not allow conclusions on the relative cost effectiveness of tax incentives compared to other policies as direct subsidies or charging infrastructure. A comparison of the effectiveness of financial incentives for hybrid electric vehicles granted in US states with gasoline prices undertaken by Diamond (2009) shows that financial incentives promote hybrid adoption, but to a much lower degree than gasoline prices.

Bjertnaes (2017) mentions some additional aspects that should be considered in the discussion about subsidising electric vehicles. Firstly, financial incentives neglect the fact that also electric cars are associated with certain externalities that should be internalised by a tax; from this perspective, substantial tax incentives are counterproductive. Secondly, in small car-importing countries that do not have a domestic car industry, tax incentives for electric vehicles can hardly be justified by the aim to encourage the domestic development of green technologies.

2.2.1.2 CO₂ differentiated vehicle taxes

Vehicle taxes can be based either on the purchase of new cars (car purchase or registration tax), or they can be levied annually in the form of circulation taxes. These taxes have been reformed in many countries since the beginning of the 2000s as to consider vehicles' carbon emission intensity. As these reforms lead to preferential tax treatment of low emission cars, vehicle taxes with tax rates differentiated according to emission intensity may be regarded as environmentally beneficial tax incentives. Several empirical evaluations can be found in the literature for either of these models; some of these evaluations offer a comparison of the effectiveness of carbon-based purchase and annual circulation taxes. Most of the existing empirical evidence focuses on individual countries. It includes ex-ante as well as ex-post analyses, some studies combine ex-post and ex-ante analyses. In addition, there is some empirical evidence on further vehicle-tax related specific tax incentives, in particular in the area of company car taxation. There is a small but growing body of studies examining the effects of various designs of vehicle-related taxes in comparison.

For the UK vehicle excise duty (an annual circulation tax based on carbon emissions rates), Cerruti et al. (2019) find that it promoted the adoption of low-emission cars and decreased sales of high-emission vehicles. Aggregate emissions decreased, albeit to a rather limited extent. Comparing the UK annual circulation tax with hypothetical alternative tax measures, the authors show that a tax proportional to carbon emissions per kilometer is twice as effective in reducing total emissions of new cars, because it leads to adjustments in miles driven. A carbon tax is half as effective. In a model-based simulation study for the UK, Brand et al. (2013) demonstrate that car purchase taxes and feebate schemes are the most effective policies to promote low-carbon technology uptake, with the further advantage of revenue neutrality. Also, an annual circulation tax is an effective, however potentially politically contested instrument. Car scrapping schemes turn out to be least favourable, as they are little effective in carbon reduction and may even increase emissions.

Klier and Linn (2015) study the CO₂ differentiated annual circulation taxes in Germany and Sweden that are linear in emission rates and find that they are less effective in reducing emission rates compared to the French car purchase tax which rests on a progressive feebate design. The authors offer two possible explanations (besides potentially differing consumer preferences). Firstly, consumers may be more responsive to purchase taxes as they expect that annual circulation taxes may be changed in the future. Secondly, the progressive design of the French car purchase tax might make it more salient compared to the Swedish and German circulation tax.

Adamou et al. (2012) simulate the effects of a revenue-neutral partial replacement of the existing car registration tax in Greece which increases considerably with engine size, with a CO₂ emissions-based tax and find that such a tax reform may lead to higher average carbon emissions of new cars. In contrast, a feebate scheme for the car purchase tax could decrease carbon emissions of new cars without negative economic consequences (e.g. in the form of large tax revenue losses).

According to Zimmermannova (2012), the introduction of an emissions-based car registration fee in the Czech Republic in 2009 caused significant environmental improvements: it increased the share of alternative fuel cars and decreased emissions from private car transport.

Replacing the engine-based registration and annual circulation tax in Ireland by an emissions-based system reduced average specific emissions of new cars by 13% in the first year; resulting not from a reduction in engine size but rather from a shift to diesel cars (Rogan et al. 2011). The reform also caused a considerable decrease of tax revenues by about one third. The ex-post assessment by Ryan and et al. (2019) finds that the reform improved the fuel economy of new cars, however at the same time supported the adoption of diesel vehicles. Giblin and McNabola (2009) provide an ex-ante simulation of the effects of the introduction of the Irish CO₂ based purchase tax. Their model predicts that the reform will reduce CO₂ emissions intensity from new vehicle purchases by 3.6% to 3.8%.

Using data from 15 EU countries for the period 2001 to 2010, Gerlagh et al. (2018) find that the increased consideration of carbon emission intensity in the design of registration taxes has decreased the carbon emission intensity of new cars only slightly, by 1.3% for the average new car; whereby a part of this decrease resulted from a higher share of diesel-fuelled cars.

In an ex-post evaluation of emission-based reforms of vehicle taxation in the Netherlands since 2007, Kok (2015) shows that the introduction of a carbon emission element in company car taxation has contributed most to lowering the emission intensity of the car fleet; followed by the reformed vehicle registration tax also differentiated according to emission intensity.

One specific feature of introducing carbon emission components in vehicle taxation that has gained some attention in tax policy rather recently is considering carbon intensity of vehicles in company car taxation. There are several country examples demonstrating that differentiating company car taxation according to carbon intensity has contributed to the reduction of carbon emissions: e.g. in the UK or the Netherlands (Kok 2015).

2.2.1.3 Feebates

More recently, feebates, combining a tax rebate for the purchase of low-emission cars and fees for the purchase of high-emission vehicles have been implemented in several countries. While the advantage of these bonus/malus schemes is that their introduction does not require additional public funds and that their revenue neutrality may increase political acceptance (Brand et al. 2013, Adamou et al. 2014), the existing empirical evaluations of this instrument yields mixed results. According to Haultfouille et al. (2016) the French "bonus/malus" feebate introduced in 2008, together with an energy label requirement introduced some years before, shifted consumer preferences towards low-emission cars beyond price effects. For the

Norwegian car registration tax applied to the purchase of new cars and based on a feebate scheme, Yan and Eskeland (2018) show that it explains the majority of the significant decrease in CO₂ intensity of new cars. The authors also find that sales of large high-emission cars are much more responsive than those of lighter low-emission vehicles. Haultfouille et al. (2014) show that consumers respond asymmetrically to the French feebate scheme in that they are more responsive to tax rebates compared to fees: resulting, in addition to the incentive to buy low-emission vehicles, in growing overall sales and therefore eventually carbon emissions. In the same vein, an ex-ante simulation of hypothetical feebates for Germany done by Adamou et al. (2014) suggests that fees must be higher than rebates to achieve welfare gains, while revenue-neutral feebate schemes are welfare decreasing. Similar asymmetric reactions by consumers are found for a long-standing feebate scheme applied in the Canadian province of Ontario by Rivers and Schaufele (2015). For Swiss cantons, Alberini and Bareit (2019) identify an only small effect of even a high malus for high-emission vehicles in annual car registration taxes regarding a shift of car sales towards low-emission vehicles. The authors show that the bonus may eventually increase net emissions by resulting in new car sales. Specifically regarding the impact of bonus/malus schemes on the retirement of old high-emission cars, Alberini et al. (2018) show for Swiss cantons that a retrospective malus applied to all high-emission cars (as in the canton Obwalden) accelerates the retirement of old inefficient cars, while a prospective malus on new cars only (as in the canton Geneva) induces car owners to postpone the retirement of their old high-emission cars.

2.2.1.4 Car scrapping schemes

Another tax incentive model which is rather well researched are car scrapping schemes, incentivizing the replacement of old by new cars. While these have been used in the past primarily as stimulus measure rather than as primarily environmentally related measures, they have an environmental impact whose direction, however, is controversial in the public debate as well as in academic research. The existing evaluations yield rather mixed evidence on the economic and environmental performance of these schemes. Altogether, empirical analyses suggest that car scrapping schemes provide only a short-run economic stimulus, have modest environmental effects only, and are not cost effective as they are associated with substantial free-rider effects.

An early study by Adda and Cooper (2000) analysing tax credits granted to individuals scrapping their old cars and buying new ones in France 1994 to 1996 finds evidence for a short-run positive economic stimulus effect, but no long-run effect. Also, government revenues are increased in the short-run but are lower in the long-run compared to the baseline scenario. Similarly, Mian and Sufi (2012), Copeland and Kahn (2013), Li et al. (2013), Gayer and Parker (2013), and Hoekstra et al. (2017), studying the "Cash-for-Clunkers" car scrapping scheme of \$ 3 billion in the US adopted to support the auto industry in the financial and economic crisis find only short-run increases of car sales which were offset in the medium run. Analysing scrapping subsidies in 8 European countries also introduced in the 2008/09 crisis, Grigolon et al. (2016) find that these considerably stabilised total car sales in the short run; long-run effects are not analysed. Studying car scrapping schemes in EU member states as stimulus measures after the

2008/09 actions in EU member states, Pollin (2011) identifies high returns in terms of short-term economic impact per unit of spending as they combine public and private financing.

Environmental effects are researched by Li et al. (2013) as well as Gayer and Parker (2013) for the US "Cash-for-Clunkers" program and by Grigolon et al. (2016) for scrapping subsidies granted during the economic and financial crises in 8 European countries. These are found to be modest for the US and slightly positive in the case of targeted European car scrapping schemes but missing for non-targeted ones. Similarly, Pollin (2011) in his study of EU Member States' car scrapping schemes identifies short-lived environmental benefits only, as a considerable share of the old vehicles would have been substituted soon anyway. Also, the simulation study by Brand et al. (2013) for the UK finds only limited emission reducing effects of a car scrapping scheme.

Li et al. (2013) and Hoekstra et al. (2017) identify substantial free-rider effects, making the evaluated car scrapping schemes little cost effective. Analysing three national car scrapping schemes (France, Germany, and the US), OECD (2011a) finds that on the one hand these indeed reduced carbon emissions and air pollution and contributed to road safety. On the other hand, the gains were overcompensated by the lost value of the scrapped cars. Gayer and Parker (2013) find that the implied cost per job created by the US "Cash-for-Clunkers" program exceeded that of alternative fiscal stimulus policies considerably. While the scheme's cost effectiveness is found to be little cost effective in terms of cost per ton of carbon dioxide reduction it caused, it was still more cost effective compared to other environmental policies, in particular the tax subsidy for the purchase of electric vehicles and the tax credit for ethanol. The authors also note that the value of the destruction of used vehicles should be balanced against the (short-lived) economic gains.

There is almost no evidence on the distributional impact of car scrapping programs. Gayer and Parker (2013) find that participants in the US "Cash-for-Clunkers" program had a higher income compared to consumers who purchased a new or used vehicle, but that their income was lower than that of consumers buying a new car outside the scrapping scheme during the same time period.

Overall, tax incentives to promote the adoption of low-emission vehicles may have mixed effects. While they appear to be effective in promoting purchases and increasing the market share of low-emission vehicles, empirical evidence also suggests various drawbacks. As mentioned above, free-riding effects are considerable, thus dampening cost effectiveness. Moreover, these tax incentives may result in a rebound effect, by increasing total car sales and thus overall carbon emissions.

2.2.1.5 Tax incentives for public transport

Tax incentives for public transport are another option to promote the de-carbonisation of transport, by furthering a shift from individual emission intensive transport modes (specifically car use) to public transport. In the literature, several arguments are put forward in favour of such tax incentives to promote public transport. Basso and Silva (2014) argue that subsidizing public transport should benefit lower incomes, who use public transport more often, over-proportionally. In addition, tax exemptions often are administratively less complex than setting up

a subsidy scheme. On the other hand, such tax incentives may be associated with free-rider effects, as (high income) households would have bought tickets for public transport anyway; thus, compared to targeted incentives, these tax incentives bear the danger of being relatively costly (Kosonen and Nicodème 2009). Not least, reduced VAT rates on public transport may encourage public transport use by a switch from even more climate-friendly modes of transportation, particularly cycling and walking.

Most common is to offer reduced VAT rates for public transport tickets; other exemptions (e.g. exempting the electricity used in public transport from electricity tax or tickets provided by the employer from employees' personal income tax on in-kind benefits) are used in a few cases only. Generally, there is hardly any empirical evidence on such tax exemptions in the area of public transport.

One crucial aspect regarding the effectiveness of tax relief for the providers of public transport (reduced VAT rates, exemption from input taxes) is whether they are passed on to consumers in the form of reduced prices. Copenhagen Economics (2007) report empirical evidence showing that VAT rate reductions will be passed through to consumers in the long run by lowering final prices. Benedek et al. (2015) qualify this finding: based on data for 17 Eurozone countries for the period 1999 to 2013, the authors show that a decrease in the regular VAT rate eventually is passed on fully to consumers, while only 30% of reductions of reduced VAT rates are passed on. For the example of a large VAT reduction for French restaurants, Benzarti and Carloni (2019) find that consumers benefited least from the reform, compared to other groups involved (suppliers, restaurant owners, etc.). Not least, Benzarti et al. (2018), using all VAT changes in the EU from 1996 to 2015, show that VAT rate reforms have asymmetric effects insofar as rate increases are passed on to consumers via price changes to a larger extent than rate reductions.

Even if tax rate reductions are passed through to consumers, the question is how price sensitive consumers are regarding price signals in public transport. According to a study by CASE/IHS/TML (2014), generally reduced VAT rates and exemptions have a limited impact, due to low elasticities of demand for passenger transport services and pass-through rates that vary between 7% and 50%. For the UK, Paulley et al. (2006) find that fare elasticities are higher in the long-run than in the short-run. The authors caution, however, that the demand for public transport is dependent on numerous factors besides fares (ranging from service quality over walk and wait time as well as wait environment, information provision and awareness campaigns to personal security), and that there is substantial uncertainty considering their relative importance.

2.2.2 Tax incentives to encourage green R&D

Generally, most countries offer tax incentives for R&D, however, not specifically for "green" R&D (OECD 2020). Belgium and Spain belong to the few exceptions. Baveye and Valenduc (2011) find the Belgian tax incentives granted to individuals and firms to encourage green R&D to be efficient. The Spanish employment and environmental investment tax credit according to an ex-post evaluation by Martínez-Ros and Kunapatarawong (2019) increased employment in SMEs and – even more markedly – for micro firms.

2.2.3 Tax incentives to encourage energy efficiency

Generally, empirical evidence is scarce, reflecting that policies to support energy efficiency of consumers and firms are dominated by other instruments, while tax incentives play a rather marginal role only. A study by The Institute of Environmental Studies (2008) focusing on reduced VAT rates as tax incentive to promote energy efficiency offers several case studies, which will, together with additional empirical analyses, be briefly reviewed in the following sections. For Belgium, Baveye and Valenduc (2011) show that the efficiency of the tax credit granted for an energy saving scheme is rather limited.

2.2.3.1 Climate-friendly energy sources

According to The Institute of Environmental Studies (2008), the reduced VAT for photovoltaic and renewable energy instalments in Portugal was not very effective. The same is true for the reduced VAT rate applied in the UK since 2000 for the installation of specific energy-saving materials. One possible reason may be that this reduction is not salient from the perspective of end consumers, as the installer and not the end consumer buys the product.

Reduced taxes for "green" electricity are another option to encourage the use of climate-friendly energy sources. A temporary exemption for green electricity from energy tax in the Netherlands between July 2001 and December 2003 markedly raised the market share of green electricity. After removal of the tax exemption, the market share of green electricity remained stable.

Alberini and Bigano (2015) find that an Italian tax credit program aiming at encouraging heating system replacement to increase energy efficiency is generally not cost effective. These results contradict an earlier analysis by Arigoni Ortiz et al. (2009) according to which tax credits for boilers appear to be a cost-effective option for Italy and for Denmark.

2.2.3.2 Energy-efficient white goods

Tax incentives for energy-efficient white goods have been rather effective, as several case studies show (The Institute of Environmental Studies 2008). For example, (temporary) VAT rate cuts for the most energy-efficient household appliances were very effective in the UK in substantially increasing sales of these appliances, while sales of products not included in the tax reduction fell considerably. An income tax credit granted in Italy since 2006 to consumers buying certain energy-efficient appliances raised their market shares markedly.

2.2.3.3 Thermal insulation

Reduced VAT rates for thermal insulation material are used in various EU Member States. According to The Institute of Environmental Studies (2008), it is questionable whether these are effective, as the material is purchased by installers and not by end consumers. Moreover, the effectiveness of VAT rate reductions may decrease in the long run, as buyers get used to the lower tax rates which were reduced in a one-off move. In a survey by the European Commission provided with regard to the experimental application of reduced VAT rates for labour-intensive services (European Commission 2003), renovation and repair of private dwellings were found to be the only sector in which service providers pass through the tax advantage,

probably due to the comparatively large level of expenditures involved. The survey also showed, however, that even if in a given sector, e.g. the repair of dwellings in the case of France, the reduced VAT rate was passed on to consumers immediately after the tax cut, consumer prices tend to be increased again after some time.

2.2.3.4 Energy-efficient equipment in industry

Ryan et al. (2012) review the evidence of tax relief programs for the Netherlands, the United Kingdom, and Ireland concerning their effectiveness and efficiency. While the programs appear to be rather cost effective, they are also associated with considerable free-riding. Moreover, the efficiency of these tax advantages is reduced by overlaps with other policies.

3. Conclusions

The fight against climate change requires effective (economic) policy instruments for policy makers. In addition to environmental taxes, such as a CO₂ tax, beneficial tax incentives that favour less polluting consumption and investment activities can be used to promote climate-friendly behaviour. Compared to the broad theoretical basis of the effects of environmental taxes, beneficial tax incentives are little represented in the theoretical literature. A beneficial tax incentive encourages behaviour that generates additional social benefits which would not have been created without the measure, with a wide variety in design of concrete measures. The empirical literature is dominated by case studies, with a strong focus on mobility related issues. Other areas covered are energy efficiency programs and beneficial tax incentives for green R&D.

Tax incentives imply foregone public revenues to favour less polluting consumption and investment activities in order to achieve environmental policy goals. Beneficial tax incentives, however, should be reviewed prior to their introduction in view of their expected effects, such as tax policy arguments, or how a specific policy objective can be achieved at the lowest cost and with the highest probability to achieve the stated goal. As beneficial tax incentives are tailored to specific circumstances, generalisable conclusions regarding their effect are difficult to draw. However, there are a number of aspects (e.g. windfall profits, picking winners, necessary budgetary funds) that should be analysed carefully before implementation.

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