Road transport electrification and motoring taxation in the UK

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Abstract

Using the Future Energy Scenarios from National Grid ESO we estimate fuel duty and VAT on fuel duty revenues from cars and vans in the UK through to 2050. We find that fuel duty and VAT on fuel duty receipts from cars and vans decrease under all scenarios. The most ambitious scenarios in terms of decarbonization, are the most problematic in terms of government revenues, which are virtually eroded by 2040. The implications are serious and require urgent action. Given that these revenues are set to all but disappear within less than two decades, a new set of road taxes needs to be introduced as a matter of urgency, potentially replacing fuel duties.

Keywords

Battery electric vehicles. Hybrid electric vehicles. Plug-in hybrid electric vehicles. Fuel taxes. Fuel tax revenues. Distance-based charge. Road pricing.

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1. Introduction

In the UK in 2019, road transport vehicles were responsible for 24% of all GHG emissions (Department for Transport, 2021a). In 2017, the UK government announced that it would "end the sale of all new conventional petrol and diesel cars and vans by 2040" (Department for Environment, Food & Rural Affairs and Department for Transport, 2017, p. 1, point 6) and in 2020 it announced that the ban would be brought forward and become effective in 2030 (Department for Transport et al., 2020). Three years later, the government pushed the ban back to 2035, setting a target of 80% of new cars and 70% of new vans to be zero emission by 2030, increasing to 100% by 2035 (Department for Transport and the Rt Hon Mark Harper MP, 2023).

Despite the ban having been moved back by five years, there is still a firm steer towards road transport electrification, helped by support for charging infrastructure (National Highways, 2021 and Office for Zero Emission Vehicles, 2022) and plug-in grants for some vehicles (UK Government, 2022), although not for cars.[1]

What is clear is that sooner or later, petrol and diesel cars and vans will disappear from the UK vehicle fleet, and non-zero low-emission vans and cars will follow suit, meaning that the sale of petrol and diesel will be drastically reduced. This is, of course, excellent news from the point of view of climate change policy.[2] The UK has committed to net-zero by 2050 (UK Public General Acts, 2019) and phasing fossil

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[1] Cars received grants from 2011 (Vaughan, 2011) to 2022, when they were stopped because the market for ultra-low emission vehicles was deemed to be mature and battery and hybrid electric vehicles made up more than 50% of all new cars sold (Department for Transport et al., 2022). Rather than re-introducing grants for cars in 2023, the government delayed the ban to "support manufacturers and families in making the switch to electric" (Department for Transport and the Rt Hon Mark Harper MP, 2023).

[2] Provided electricity is generated in a clean manner, electric vehicles are the most feasible path to decarbonize road transport (Liu and Santos, 2015; Woo et al., 2017; Cox et al., 2020; Gryparis et al., 2020; Gómez Vilchez and Jochem, 2020; Sobol and Dyjakon, 2020; Märtz et al., 2021; Logan et al., 2022). Electric vehicles, however, will not solve other externalities such as congestion, accidents or air pollution. In fact, electric vehicles could increase distances travelled, as the operating cost per kilometre are substantially lower than the operating costs of petrol and

fuels out is not just necessary but essential. The side-effect of this, however, is that the revenues from motoring taxation, which consist primarily of fuel duties, will be eroded.

The revenues from fuel duties as a percentage of total tax revenues are in decline, as can be seen in Figure 1. The ratio of revenues from fuel duties to GDP is also in decline, as can be seen in Figure 2.[3] The reason for this is threefold: first, the fuel efficiency of petrol and diesel vehicles has increased over time and therefore these vehicles use less fuel, and obviously pay less fuel duty, second, these duties have not kept up with inflation, and third, their share in the overall vehicle stock has been decreasing, albeit very slowly.

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diesel vehicles, and purchase prices will eventually reach cost parity (Hensher et al., 2021). Greater distances travelled would have impacts on congestion and accidents. The costs of accidents involving an electric vehicle and an internal combustion engine vehicle can be higher than the costs of accidents involving only internal combustion engine vehicles because of the difference in weight (Shaffer et al., 2021). People using the car more, would also reduce the use of public transport (Hensher et al., 2021). In addition, electric vehicles, just like internal combustion engine vehicles, produce particulate matter from tyre and brake wear and road abrasion. This means that although pollution from fossil fuel combustion would be eliminated with electric vehicles, non-tailpipe pollution, would not (Quarmby et al., 2019; Hensher et al., 2021). In the UK in 2021, the latest year for which statistics are available, 15.1% of PM_{10} emissions from road transport were from exhaust emissions, 58.1% were from tyre and brake wear, and 26.8% were from road abrasion, with the numbers for $PM_{2.5}$ being 24.7%, 51.7%, and 23.6%, respectively (Department for Transport, 2022a, ENV0301).

[3] In 2008-09, due to the global economic downturn, the GDP in the UK fell, as did total tax revenues. Revenues from fuel duties did not decrease, probably because the demand is inelastic. This explains the temporary increase in the ratios presented in Figures 1 and 2.

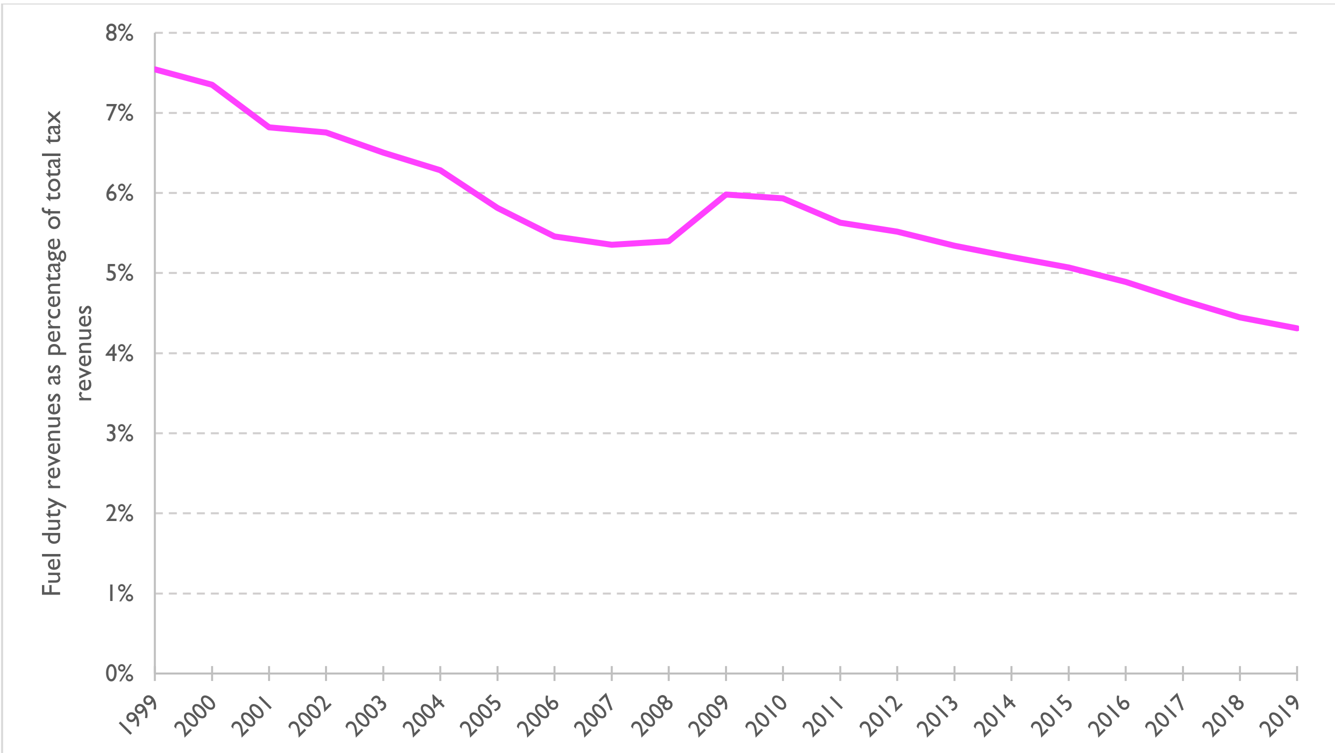

Figure 1: Fuel duty revenues as percentage of total tax revenues, 1999-2019

Source: Department for Transport (2021b, TSGB1310); HM Revenue & Customs, HMRC (2021)

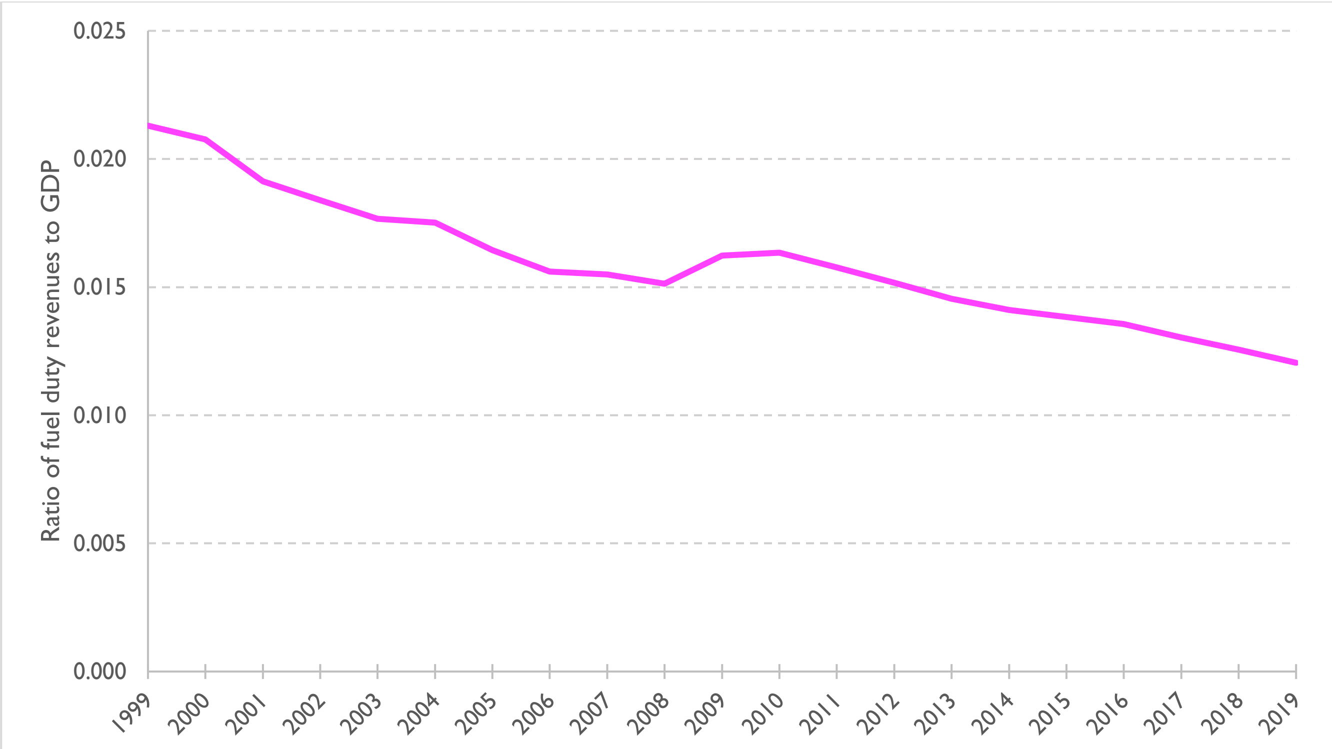

Figure 2: Ratio of fuel duty revenues to GDP, 1999-2019

Source: Department for Transport (2021b, TSGB1310); HM Treasury (2022)

In the present study we dig into this problem, taking into account the different paths that the uptake of low- and zero emission vehicles could take. The aim of the research is to estimate future loss of tax receipts from fuel duty, and also from Value Added Tax (VAT) on fuel duty, from cars and vans in the UK in the period leading up to 2050. In order to do this, we model revenues under different scenarios, which assume different trajectories in the composition of the vehicle fleet. The reason why we focus on cars and vans is that, together, they represent 93% of the total UK vehicle fleet[4] (Vehicle Licensing Statistics, 2021a, VEH0101) and are the vehicles that will increasingly become low- and zero emission.

The paper proceeds as follows. Section 2 presents the context and reviews the scarce literature on the topic of eroding revenues from fuel taxes due to an increase in the share of electric vehicles. Section 3 explains the methodology used and Section 4 presents and discusses the results. Section 5 concludes and provides some policy recommendations.

[4] This number has remained virtually constant since at least the mid-1990s (Vehicle Licensing Statistics, 2021a, VEH0101).

2. Context and previous work

Fuel duties in the UK are amongst the highest in Europe (Santos, 2017; Adam and Stroud, 2019; International Energy Agency, 2018). In the UK, neither petrol nor diesel taxes fully internalize road transport externalities.[5] However, fuel taxes in the UK, and in most countries in Europe, do internalize the climate change externality (Santos, 2017, Organization for Economic Cooperation and Development, 2021). Despite fuel taxes in the UK being very high and internalizing the climate change externality, CO2 emissions from road transport are still high and need to be drastically reduced to help the country reach net-zero by 2050.

In the UK, fuel duty is levied per unit of fuel purchased and is included in the price paid at the pump for petrol, diesel and other fuels used in vehicles (Office for Budget Responsibility, 2023a). The standard rate for petrol and diesel in the UK has been 57.95 pence per litre since 2011-12,[6] although there is a temporary cut of 5 pence, effective from April 2022 and due to end in March 2024 (Office for Budget Responsibility, 2023a). VAT is applied to both the pre-tax price of fuel and to the fuel duty.

The other motoring tax is the vehicle excise duty (Driver & Vehicle Licensing Agency, 2022). This is a tax paid by all vehicles for the use of public roads in the UK. For cars registered before April 2017, the vehicle excise duty depends on the car's official CO2 emissions (Office for Budget Responsibility, 2023b). For cars registered from April 2017 onwards, the vehicle excise duty payable in the first year depends on the car's CO2 emissions but the vehicle excise duty payable in subsequent years does not (Office for Budget Responsibility, 2023b). For vans, the vehicle excise duty varies according to when they were registered and the Euro-standard they are compliant with (Driver & Vehicle Licensing Agency, 2022).

Zero emission vehicles do not pay vehicle excise duty (Driver & Vehicle Licensing Agency, 2022), but this exemption will be removed from April 2025 onwards for both new and existing zero emission vehicles (HMRC, 2022). All cars will pay the same vehicle excise duty, regardless of whether they are internal combustion engine, hybrid, plug-in hybrid, or electric. The same will be the case with vans. This measure

[5] This is also the case in most countries in Europe (Santos, 2017) and around the world (Parry et al., 2014; Parry et al., 2021).

[6] This means that the rate has decreased in real terms over the years.

will ensure that vehicle excise duty revenues are preserved as the fleet is electrified. Revenues from vehicle excise duties are earmarked to fund local and strategic road upgrades (House of Commons Transport Committee, 2022) and are therefore very important, despite representing only around 0.7% of all receipts (Office for Budget Responsibility, 2023b).

The share of electric cars and vans in the total vehicle stock in the UK is still very low, but is increasing, as can be seen in Figures 3 and 4, and will continue to increase, as discussed in Section 4.

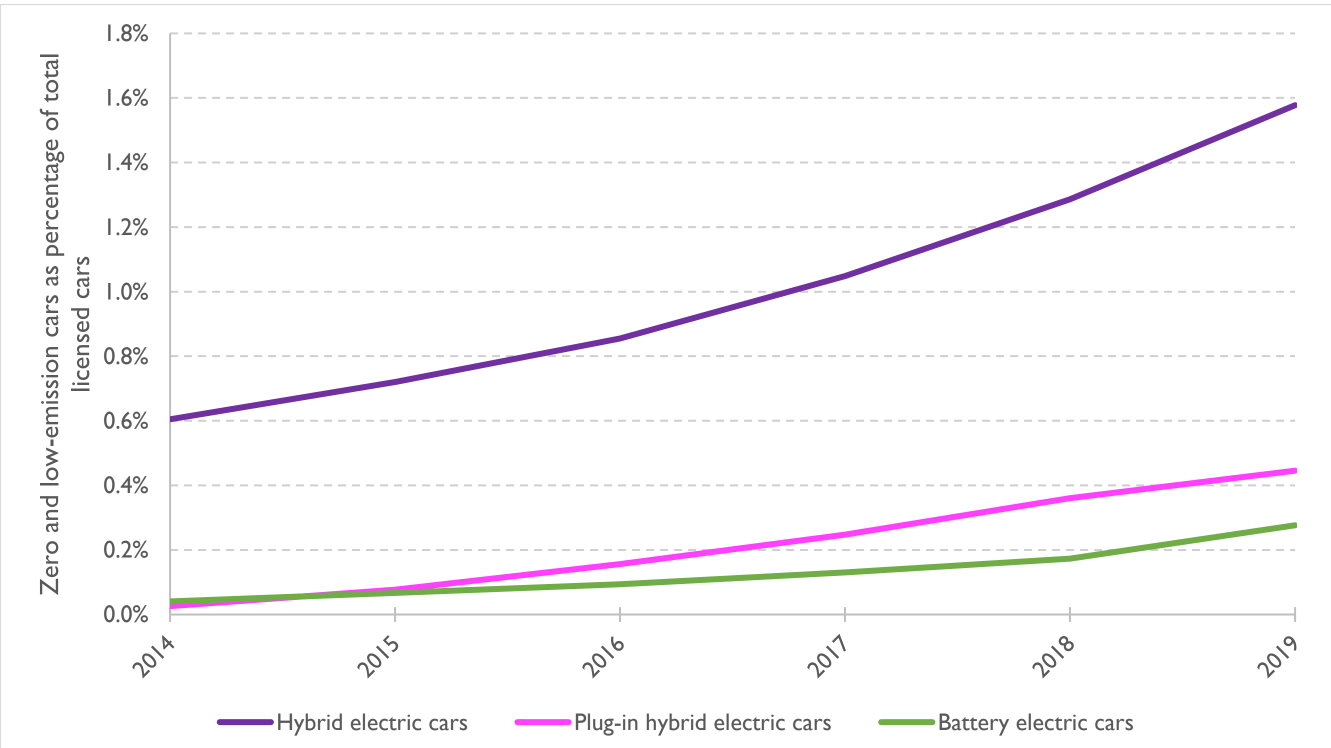

Figure 3: Zero and low-emission cars as percentage of total licensed cars, 2014-2019

Source: Vehicle Licensing Statistics (2021b, VEH0203)

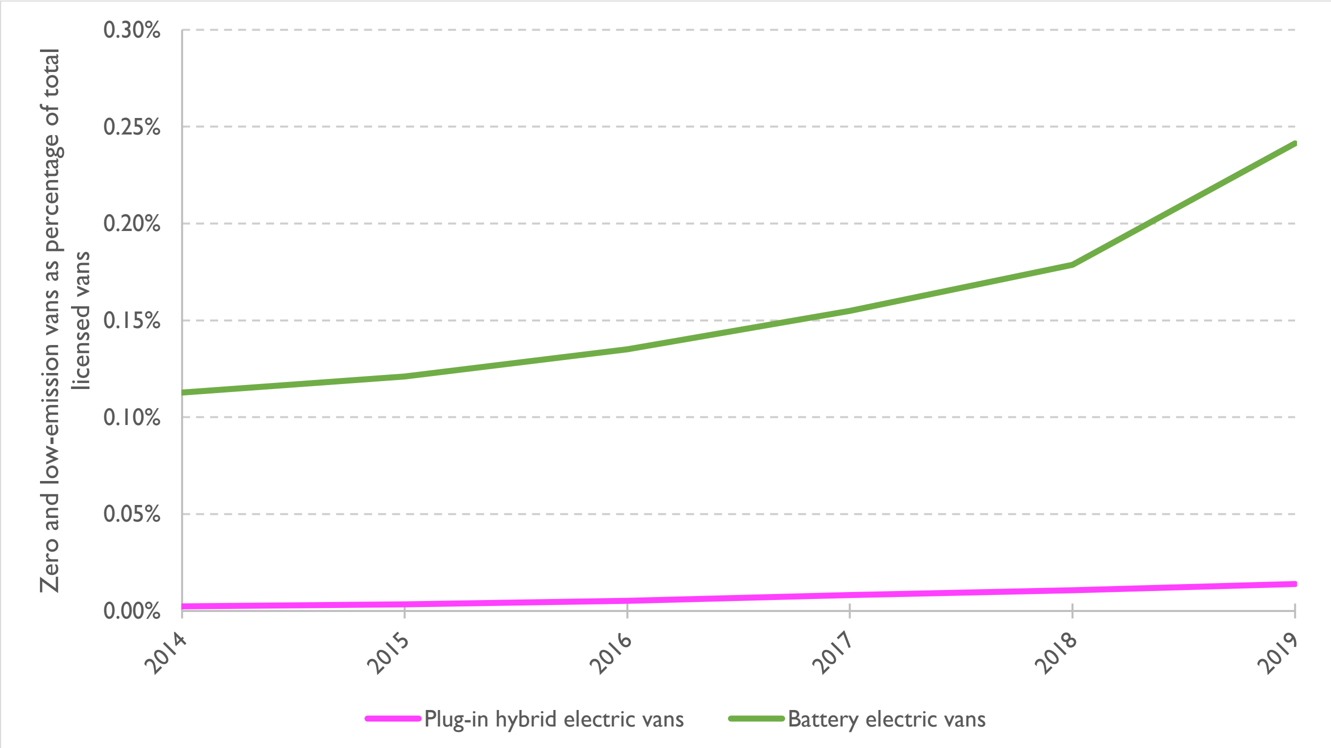

Figure 4: Zero and low-emission vans as percentage of total licensed vans, 2014-2019[7]
Source: Vehicle Licensing Statistics (2021c, VEH0403; 2021d, VEH0133a)

By equalizing the vehicle excise duty of alternatively fuelled vehicles and internal combustion engine vehicles from 2025 onwards, the government has ensured that stream of revenues, with probably no impact on consumers' choices given the negligible amount of the vehicle excise duty relative to the purchase price of a vehicle. However, in the context of fuel duties, the government is facing a trade-off. On the one hand, zero emission vehicles need to be taxed, not just to collect revenues but also to internalize non-climate change externalities such as for example, congestion (Davis and Sallee, 2020), which may increase with electric vehicles due to their reduced energy cost per kilometre[8] (Hensher et al., 2021), or non-tailpipe air pollution, and on the other hand, reducing the gap between taxes paid by zero emission vehicles and fuel taxes paid by petrol and diesel vehicles may delay the shift to clean vehicles (Jenn et al., 2015; Adam and Stroud, 2019), as tax incentives are key (Santos and Davies, 2020).

[7] Hybrid electric vans have been omitted from the figure because their number is negligible.

[8] This is known as the rebound effect.

Fuel duty revenues are the seventh single biggest revenue stream for the Treasury (Butcher and Davies, 2020). They are not earmarked but go to the consolidated fund and are used to fund public services, such as for example, schools, hospitals and the armed forces (House of Commons Transport Committee, 2022). As the share of electric vehicles increases, revenues from fuel duties will disappear, as we show in Section 4.

This shortfall in revenues is not a problem that will affect just the UK. It is a problem that will affect all countries eventually, as the fleet of motor vehicles is electrified. There have been concerns regarding the eventual erosion of the road fuel tax base since electric vehicles were deemed as the way forward.

Brady and O'Mahony (2011), for example, conduct an early analysis of what was, back when they did their research, a proposal to deploy 230,000 electric vehicles in Ireland by 2020. Their result of a loss of between 0.5% to 1% of total tax revenue never materialized because the target was missed. By the end of 2020, there were just over 26,000 battery electric vehicles and plug-in hybrid electric vehicles registered in Ireland (Irish Parliamentary Budget Office, 2021, p. 12). The potential problem, however, remains. Even if the new target of one million electric vehicles in Ireland by 2030 is not met, there will be an increase in revenue losses from motor tax, VAT, fuel duties, and the carbon tax if mass electrification of the vehicle fleet in Ireland materializes (Irish Parliamentary Budget Office, 2021, p. 18). Furthermore, if full electrification is achieved by 2050, around 8% of total revenues could be lost (Irish Parliamentary Budget Office, 2021, p. 4).

The situation is already very concerning in Norway, which has the highest share of zero-emission cars and sales in the world, at 16% and 64.5%, respectively, in 2021 (International Energy Agency, 2022), and where revenues from motoring taxes have decreased substantially (Meaker, 2021). To tackle the problem, the government is currently considering new forms of charging (The Norwegian Tax Administration, 2022).

Even countries like the United States, Australia and Mexico, all of which have amongst the lowest fuel taxes in OECD countries (International Energy Agency, 2018, pp. xxvi-xxvii), will see a decrease in tax revenues as a result of road transport electrification.

Jenn et al. (2015) estimate the impact of electric vehicle adoption on revenues from fuel taxes in the United States. They conclude that the decrease in revenues by 2025 would be between $200 million for a base case electric vehicle uptake and $900 million for a fast electric vehicle uptake. This is a very small sum when compared, for example, to the total federal government revenues in the fiscal year 2023, which were $3.97 trillion (US Treasury, 2023). This is not surprising, given the small share of electric vehicles in the total vehicle stock in the United States, which was less than 1% in 2021 (Cage, 2022), and how low road fuel taxes are (International Energy Agency, 2018, pp. xxvi-xxvii). Nonetheless, given that fuel tax revenues in the United States collected at federal and state level are mainly allocated to fund and maintain transport infrastructure, the problem is one of growing importance, with annual expenditures on transport infrastructure already larger than the funding available (Jenn et al., 2015).

Davis and Sallee (2020) also look into the problem and estimate that what is still a modest reduction in fuel tax revenues in the United States could become very sizeable by 2030 under a strong electric vehicle market penetration assumption.

We note that in the United States, fuel taxes vary across states. This is because they include a federal excise tax, which is 18.4 cents per gallon for petrol and 24.4 cents per gallon for diesel, a state excise tax, which spans a wide range, and in most cases, an additional state tax or fee, which also spans a wide range, and is set for a variety of reasons, such as for example, environmental protection, storage underground tank release, inspection, and clean-up, to name just a few. As a result, the total (federal and state) tax ranges from 27.35 cents per gallon for petrol and 33.35 cents per gallon for diesel in Alaska, to 86.52 cents per gallon for petrol and 105.22 cents per gallon for diesel in California, with a whole country average of 47.85 cents per gallon for petrol and 55.21 cents per gallon for diesel[9] (US Energy Information Administration, 2023).

Kolpakov and Sipiora (2020) zoom into the state of Florida, and conclude that the decrease in (state and federal) revenues due to electric vehicles will increase over time, from 0.2% of fuel tax revenues in 2019-2020 to 1.7% by 2029-2030.

[9] These are the rates effective as of July 2023.

Konstantinou et al. (2023) focus on the state of Indiana and find that state wide fuel tax revenues would decrease by 21% from 2030 to 2035, assuming a 5% electric vehicle market penetration for light-duty vehicles, and a 30% market penetration for medium/heavy duty vehicles.

The potential reduction in government revenues is also seen as a problem in Australia, where 37% of revenues from road vehicles come from fuel duties (Infrastructure Partnerships Australia, 2019; Hensher et al., 2021). This poses a challenge and alternative sources of revenue are being sought. In July 2021, the state of Victoria introduced a zero and low emission vehicles charge, but in October 2023, the High Court determined that the charge was unconstitutional because it was an excise, which cannot be imposed by states (Byrne, 2023). At the time of writing this paper, the state of New South Wales is planning to introduce an almost identical charge in July 2027 or when electric vehicles reach 30% of all new vehicle sales, whichever comes first (NSW Government, 2023). However, the judgement from the High Court regarding the unconstitutionality of the zero and low emission vehicles charge in Victoria may now prevent New South Wales, and indeed any other jurisdiction, from introducing such a charge.

Bonilla et al. (2022) concentrate on Mexico, and find that an increasing share of electric vehicles that reaches 30% of the total vehicle fleet by 2050, could cause a cumulative loss in fuel tax revenues from 2020 to 2050 ranging from 17.4% to 44.5%, relative to what would have been raised with a petrol only fleet.

What is clear from the literature reviewed is that motoring tax revenues are already in decline in a number of countries, and that the problem will only get worse as road transport is electrified, an essential step towards decarbonization. The speed of the decrease in revenues will obviously depend on the speed of the electrification of the vehicle fleet. To our knowledge, no study currently exists with a projection of tax revenues through to 2050 under different scenarios in the UK. We attempt to fill this research gap with the present paper. The section that follows describes the model used to estimate the possible courses that this declining trend in tax revenues could take.

3. Model and data

The data used in the present study is data from the Future Energy Scenarios produced by National Grid ESO (2021b) combined with additional data published by the UK government, as explained in the sections that follow.

The four scenarios are Steady Progression, Consumer Transformation, System Transformation and Leading the Way (National Grid ESO, 2021a; 2021b; 2021c). Table 1 summarizes the main assumptions under each scenario.

Steady Progression ▪ Slowest credible decarbonization. ▪ Minimal behavioural changes by consumers. ▪ Gradual decarbonization in power generation and transport but not in heating, which continues to rely on natural gas. ▪ Ban on the sale of new petrol and diesel cars effective from 2035. ▪ Ban on the sale of new plug-in hybrid electric vehicles and new petrol and diesel vans effective from 2040.
Consumer Transformation ▪ Consumers willing to change travel behaviour, including switching to more sustainable and active travel. ▪ High energy efficiency and electrified heating. ▪ Ban on the sale of new petrol and diesel cars and vans effective from 2030. ▪ Ban on the sale of new plug-in hybrid electric vehicles effective from 2035.
System Transformation ▪ Most changes in the energy system take place on the supply side. ▪ Hydrogen boilers in homes.

▪ Hydrogen produced from natural gas with Carbon Capture and Storage.[10] ▪ Ban on the sale of new petrol and diesel cars effective from 2032. ▪ Ban on the sale of new plug-in hybrid electric vehicles and new petrol and diesel vans effective from 2035.
Leading the Way ▪ Fastest credible decarbonization. ▪ Significant behavioural changes in consumers, including switching to more sustainable and active travel. ▪ Mixture of hydrogen and electrification for heating. ▪ Hydrogen not produced from natural gas, but from electrolysis powered by renewable electricity. ▪ Ban on the sale of new petrol and diesel cars and vans effective from 2030. ▪ Ban on the sale of new plug-in hybrid electric vehicles effective from 2032.

Table 1: Main assumptions of the Future Energy Scenarios

Source: National Grid ESO (2021a, 2021c)

The Future Energy Scenarios are different potential paths that the UK could follow in the area of energy generation and energy consumption (National Grid ESO, 2021a). Future government policies will determine the path the UK will follow, and this path may be a combination of the paths outlined by the different scenarios, which range from one with slow decarbonization to one with very rapid decarbonization. Government policies can shape action from businesses and consumers, whether this is investment in new technologies or behavioural change.

3.1 Types and number of cars and vans

Projections on the numbers of different types of cars and vans through to 2050 were fundamental for making projections of fuel duty revenues. The biggest reduction in fuel duty revenues between 2020 and

[10] Carbon Capture and Storage are technologies that collect CO2 at emission sources or remove it directly or indirectly from the atmosphere, transport it and bury it (British Geological Survey, 2021).

2050 will come from the reduction in the number of cars and vans that are propelled in whole or in part by fossil fuels. For this reason, we focused on cars and vans. The different types of cars and vans considered were petrol cars, diesel cars, hybrid electric cars, which have a battery that is charged while the fuel is used to motor the engine (HEV cars), plug-in hybrid electric cars (PHEV cars), battery electric cars (BEV cars), and hydrogen cars. The same categories, except HEV, were also used for vans (petrol, diesel, PHEV, BEV and hydrogen). The number of HEV vans on the roads as of 2022 is negligible and can be ignored. The four scenarios from National Grid ESO (2021b) assume different rates of decarbonization of road transport, and so they project different numbers of all these types of vehicles through to 2050, except for HEV cars, which are not considered, modelled or included in any of the scenarios. Starting with the actual number of HEV cars in 2020, taken from Vehicle Licensing Statistics (2021b, VEH0203), we assumed that their number would grow at the same rate as the number of PHEV cars under each scenario.

The ban on hybrid electric vehicles is set to kick in five years after the ban on petrol and diesel vehicles under all four scenarios. It is not completely clear if the ban will treat PHEVs and HEVs in exactly the same way, but from Department for Transport et al. (2020) it would appear it will, and so this is what we assume in the present study.

For petrol and diesel cars, we assumed that the share of diesel would decrease over time, as this is a trend already evident (Vehicle Licensing Statistics, 2021b, VEH0203), probably because of the 2015 diesel-gate (Hotten, 2015) and clean air zones that continue to be implemented across the UK (Bose et al., 2021).[11] A rolling reduction in the share of diesel vehicles from 40% to 20% of total diesel and petrol cars

[11] Between 1999 and 2016, amongst petrol and diesel cars, the share of diesel cars increased from 12% to 41% (Department for Transport, 2021b, TSGB1310). This increase was driven by government policy to reduce CO2 emissions from road transport. Although CO2 emissions from diesel are higher than CO2 emissions from petrol when measured in kg of CO2 emitted per litre of fuel, CO2 emissions from diesel are always lower than CO2 emissions from petrol when measured in kg of CO2 emitted per vehicle-kilometre because diesel has a higher fuel efficiency than petrol. It was hoped that dieselization of the car stock would help reduce CO2 emissions from road transport. The problem is that air pollution is higher for diesel than for petrol, even when measured per vehicle-kilometre. Furthermore, diesel was classified as 'carcinogenic' by the WHO in June 2012 (International Agency for Research on Cancer, 2012). The diesel-gate followed in 2015, and air pollution became very important in the

was therefore assumed from 2020 to the year they are eventually phased out under each scenario: 2045 under Scenario 1 (Steady Progression), 2041 under Scenario 2 (Consumer Transformation), 2043 under Scenario 3 (System Transformation), and 2040 under Scenario 4 (Leading the Way).

Diesel and petrol vans also eventually disappear from the roads under all scenarios, except for Scenario 1 (Steady Progression). The year they are phased out is 2044 under Scenario 2 (Consumer Transformation), 2043 under Scenario 3 (System Transformation), and 2040 under Scenario 4 (Leading the Way). In contrast with the share of diesel cars, the share of diesel vans has been steadily increasing relative to petrol (Vehicle Licensing Statistics, 2021c, VEH0403).[12] For this reason, we assumed that the share of diesel relative to petrol vans would continue to increase and reach 98% by the time they eventually disappear in Scenarios 2, 3 and 4. In Scenario 1 the share of 98% diesel is reached in 2050, the last year modelled.

3.2 Fuel duty receipts

To model fuel duty receipts for the period 2020-2050, we made assumptions based on the average amount of fuel duty paid by each vehicle/propulsion type in a given calendar year.

The average amount of fuel duty paid by each individual vehicle/propulsion type for each calendar year throughout the period 2020-2050 was calculated based on a combination of total vehicle km travelled, sourced from TRA0101 (Department for Transport, 2021c), proportions of vehicle km by fuel type, sourced from TAG A1.3.9 (Department for Transport, 2022b), average fuel consumption of new cars and vans, sourced from ENV0103 (Department for Transport, 2021d), and forecasted fuel efficiency improvements, sourced from TAG A1.3.10 (Department for Transport, 2022b).

When forecasting future vehicle km travelled, the base year was 2019 and we assumed that the average total distance travelled in a calendar year calculated for each vehicle type would remain the same throughout the period 2020-2050. Figure 5 demonstrates that average distances travelled by cars and vans

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transport policy agenda. As a result, the share of diesel cars between 2017 and 2020 decreased, as evidenced by (Department for Transport, 2021b, TSGB1310), a trend very likely to continue.

[12] Vans are mainly working vehicles and tend to run on diesel because diesel engines yield better economy and load-carrying ability, although with less power and a slower response time.

have remained relatively constant over the period 2000-2019. This has been so despite increases and decreases in crude oil prices (Trading Economics, 2022)[13] and a recession (Office for National Statistics, 2018).[14] In 2020 there was a large decrease in average distances driven as a result of travel restrictions imposed during the Coronavirus pandemic. Given that distance travelled has remained constant over 2000-2019, we assumed that distance travelled in 2019 would be the average distance travelled through to 2050, and for modelling purposes, we ignored the reduction in average distance travelled over 2020.

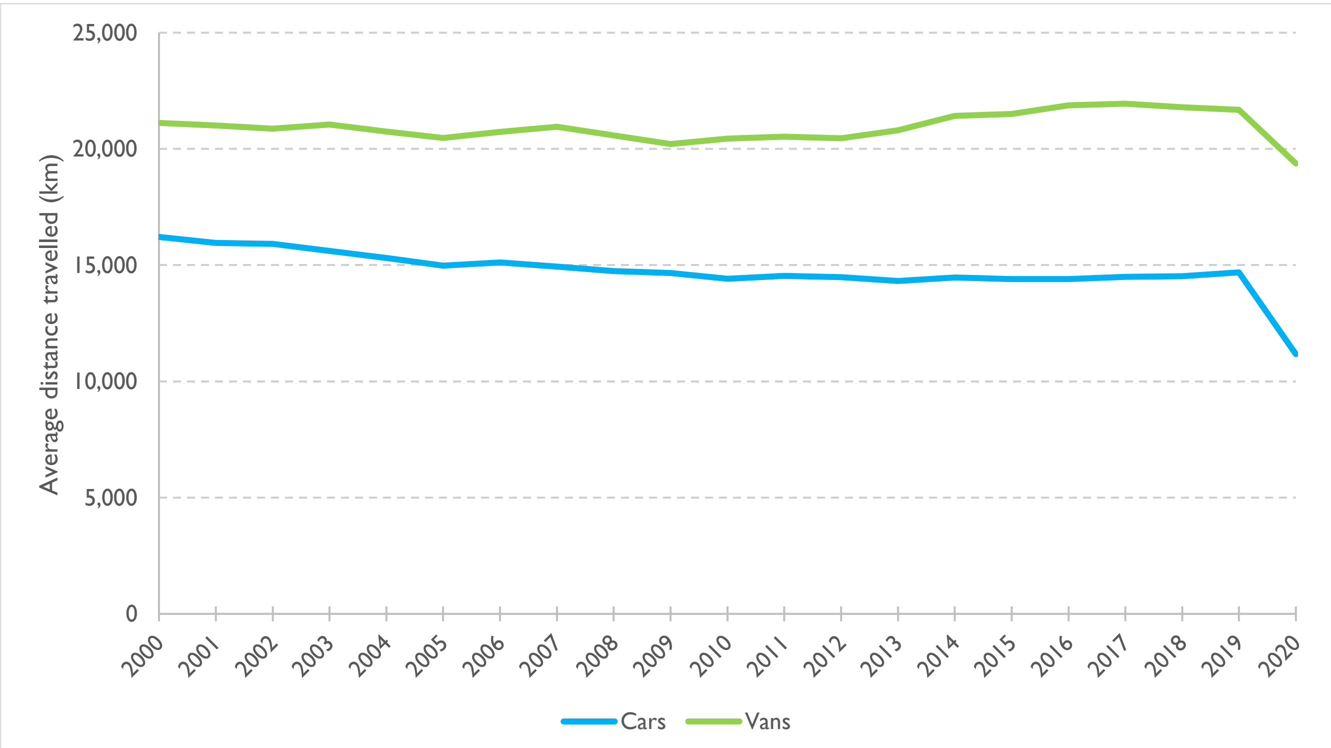

Figure 5: Average distance travelled by cars and vans (km), 2000-2020

Source: Department for Transport (2021c, TRA0101) and Vehicle Licensing Statistics (2022, VEH0103)

Improvements in fuel efficiency year on year for petrol and diesel vehicles were taken from TAG A1.3.10 (Department for Transport, 2022b). For HEV cars fuel efficiency was assumed to increase by the same percentage as that for petrol cars. For PHEV cars and vans fuel efficiency was also taken from TAG

[13] The price of Crude Oil WTI touched US$140 per barrel in 2008, and dipped under US$20 per barrel in 2001 and in 2020 during the Coronavirus pandemic (Trading Economics, 2022).

[14] The UK economy shrank by more than 6% between the first quarter of 2008 and the second quarter of 2009 and took five years to get back to where it was before the recession (Office for National Statistics, 2018).

A1.3.10 (Department for Transport, 2022b), although these are labelled as “electric” there because they are treated together with BEVs.

The fuel duty in the UK has been 57.95 pence per litre for petrol and diesel since 2010 and is assumed to remain constant across the period 2020-2050,[15] except for the period April 2022-March 2024, when there was a temporary cut of 5 pence and the fuel duty was 52.95 pence per litre (Office for Budget Responsibility, 2023a).

The average annual fuel duty paid by each vehicle type (petrol car, diesel car, petrol van, diesel van, PHEV car, PHEV van, and HEV car) in a given year was therefore calculated as the annual average fuel consumption of that vehicle type multiplied by the fuel duty. The average fuel consumption by vehicle type in a year was estimated as the average distance travelled by that vehicle type in a year multiplied by the average fuel efficiency for that vehicle type for that year (measured in litres per km).

There are no readily available statistics for PHEV cars, due to their still relatively low numbers. We therefore assumed that fuel consumption by PHEV cars was 1.65 litres/100km, which is the average fuel consumption of 22 PHEV car models, as submitted by the manufacturers (Nagra, 2021). We also assumed that the annual average distance travelled by PHEV cars and vans was the same as BEV cars and vans as these are treated together on TAG A1.3.9 (Department for Transport, 2022b). The average distance travelled by PHEV and BEV cars was estimated as the percentage of car km travelled by electric cars, sourced from TAG A1.3.9 (Department for Transport, 2022b) multiplied by the total car km travelled, sourced from TRA0101 (Department for Transport, 2021c). This total figure was then divided by the total number of licensed BEV and PHEV cars to obtain the average distance driven per PHEV and BEV cars in 2019, which was then assumed to remain constant through to 2050, as explained above. The average distance travelled for PHEVs is higher than for petrol cars, which supports real world findings (Patton, 2020; Plötz et al., 2020).

For PHEV vans, the Ford Transit Custom PHEV is the only PHEV van on the UK market (Hubbard, 2021). We therefore assumed that all PHEV vans start with an average consumption of 3.05 litres/100km in 2020, based on weighted average fuel consumption figures from Ford (2021) for this model. Average

[15] This assumption is in line with what National Grid ESO (2021b) does.

distance travelled by PHEV vans was calculated using the same methodology as for PHEV cars, with data for vans also sourced from TAG A1.3.9 (Department for Transport, 2022b) and TRA0101 (Department for Transport, 2021c).

For HEV cars, an average fuel efficiency figure of 3.8 litres/100km was assumed for 2020, based on Santos and Rembalski (2021), and this was assumed to improve by the same percentage per year as the fuel efficiency for petrol cars. The average distance travelled by HEV cars was assumed to be the same as for petrol cars.

3.3 Value added tax

Value Added Tax (VAT) is applied not just on the pre-tax price of fuel but also on fuel duty. For example, if the fuel duty is 57.95 pence per litre, the VAT on fuel duty at 20%, is 11.59 pence per litre. Working vehicles, such as taxis and vans used for work, can get a full VAT rebate, including the VAT paid on the pre-tax price of fuel and the VAT paid on fuel duty. If a taxi or van is used for both private and business travel, then the VAT can be claimed for the fuel used when driving for business.

VAT receipts from fuel and fuel duty will also decrease. The government can, in principle, recover at least part of the lost VAT on the pre-tax price of fuel via the VAT on electricity.[16] However, the lost VAT on fuel duty cannot be recovered unless a similar duty is introduced elsewhere and VAT is charged on it too.

We produced a rough estimate of VAT on fuel duty likely trends under the four scenarios by assuming that all vans are working vehicles and currently receive a VAT rebate, and all cars are non-working vehicles, and none currently receive a VAT rebate. There are, of course, a minority of vans used for private travel, and a minority of cars used as working vehicles. However, it can be expected the differences in VAT receipts will cancel out.

[16] VAT is charged at a reduced rate of 5% on electricity for domestic and residential use, including charging of electric vehicle batteries.

3.4 Constant prices

All monetary values are expressed in 2020 prices. To do this, the GDP deflator from the Annual Parameters sheet of the TAG Data Book (Department for Transport, 2022b) was used.[17]

4. Results

4.1 Petrol and diesel cars and vans

Figures 6 and 7 show the number of petrol and diesel cars and vans under the different scenarios. This is important because the quicker these disappear from the roads, the quicker the reduction in revenues from fuel duties will be. Leading the Way is, by far, the most ambitious scenario, and this is clearly reflected on both figures, with a fast decrease in petrol and diesel vehicles on the roads. The Steady Progression scenario represents the slowest credible decarbonization of road transport (National Grid ESO, 2021b). Although slow, this scenario closely matches current EU policy ambitions set out in the European Green Deal (European Commission, 2021a, 2021b). The Consumer Transformation scenario assumes that the ban on the sale of new petrol and diesel cars and vans becomes effective in 2030, followed by the ban on the sale of new plug-in hybrid electric vehicles in 2035. It also assumes that consumers switch to sustainable transport and active travel, which helps achieve a fast reduction in the number of petrol and diesel vehicles on the road. The System Transformation scenario assumes the bans are implemented in 2032 for the sale of new petrol and diesel cars, and in 2035 for the sale of new PHEVs and new petrol and diesel vans. It also assumes that consumers are not very inclined to change to sustainable transport or active travel. As a result, the number of petrol and diesel cars and vans does not decrease as fast as it does under the Consumer Transformation and Leading the Way scenarios.

[17] A note of caution needs to be made because, although the numbers reported in the Annual Parameters sheet of the TAG Data Book (Department for Transport, 2022b) rest on forecasts made by the Office for Budget Responsibility (2021, 2022), they are long term trends and are therefore subject to some degree of uncertainty.

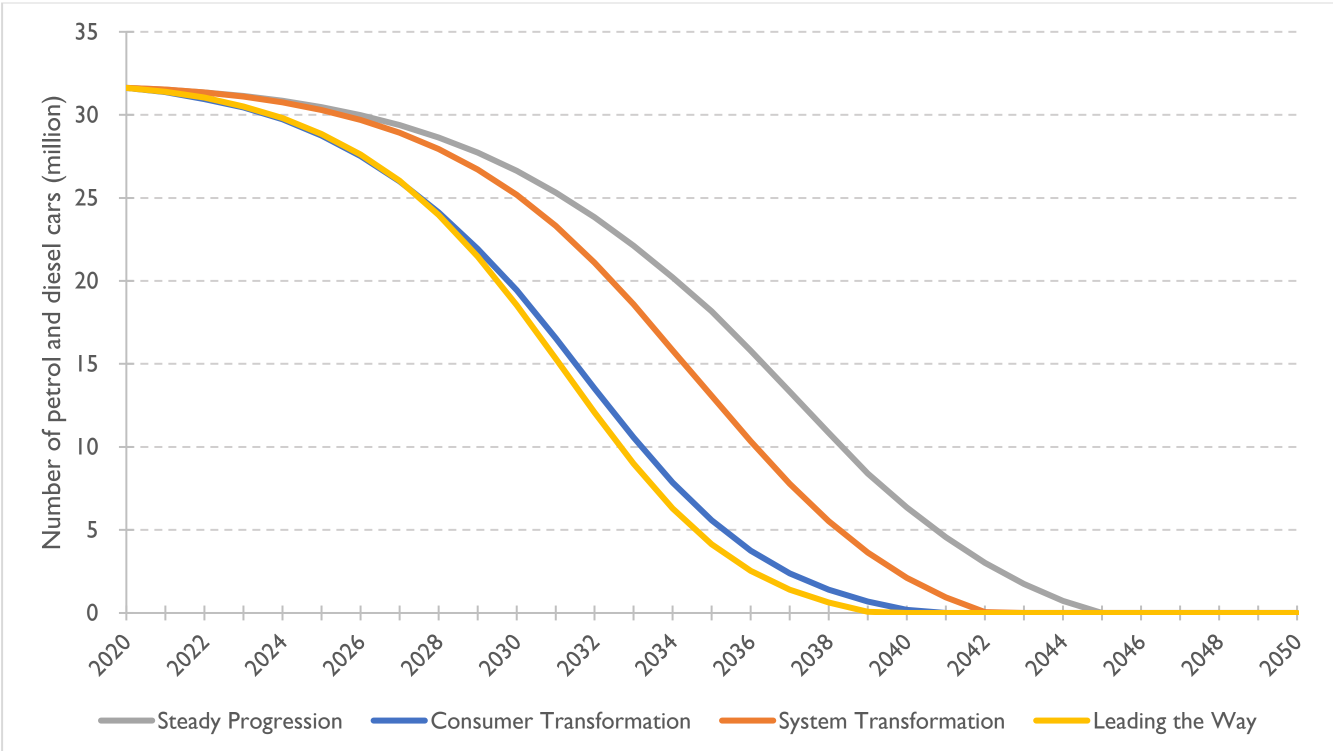

Figure 6: Number of petrol and diesel cars under the four scenarios (million), 2020-2050

Source: National Grid ESO (2021b)

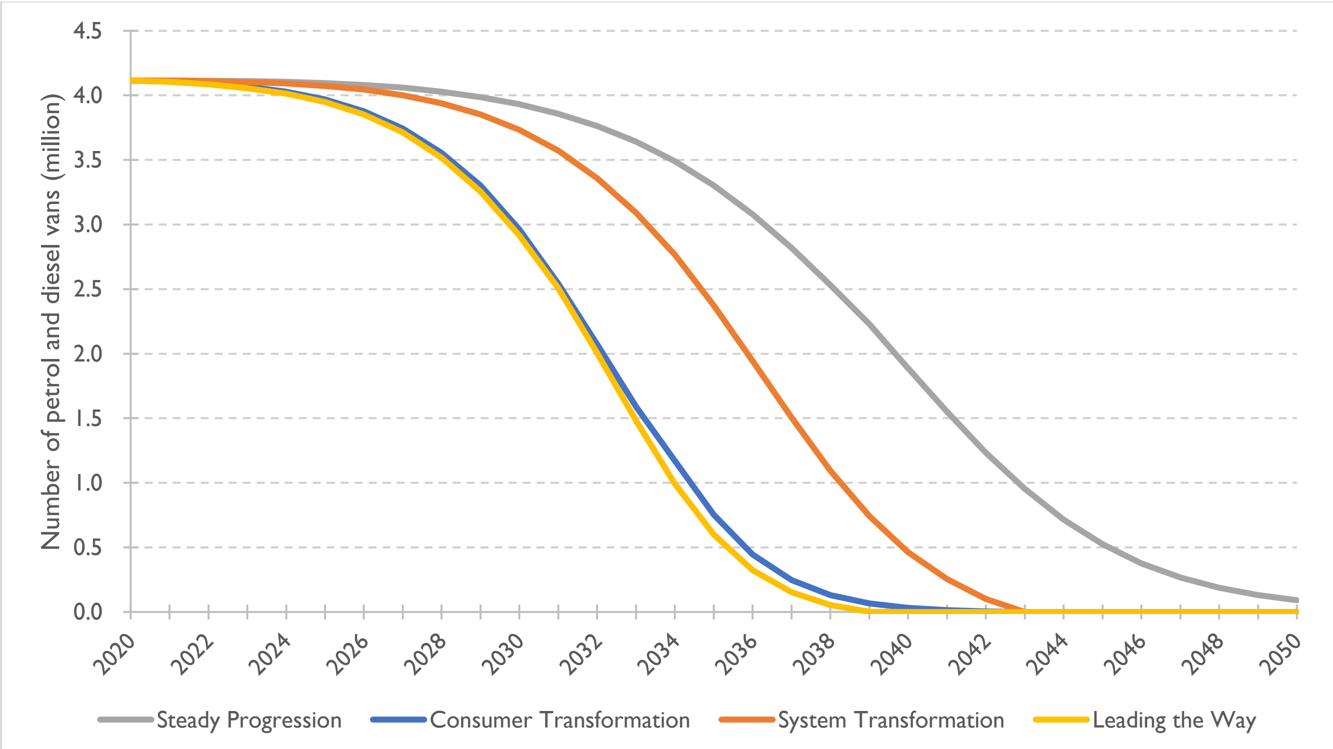

Figure 7: Number of petrol and diesel vans under the four scenarios (million), 2020-2050

Source: National Grid ESO (2021b)

4.2 Fuel duty and VAT receipts

As expected, fuel duty receipts from cars and vans decrease under all scenarios. Figures 8 and 9 show revenues from fuel duties under all scenarios at 2020 prices, without and with the 5 pence temporary reduction in fuel duty over 2022-24.

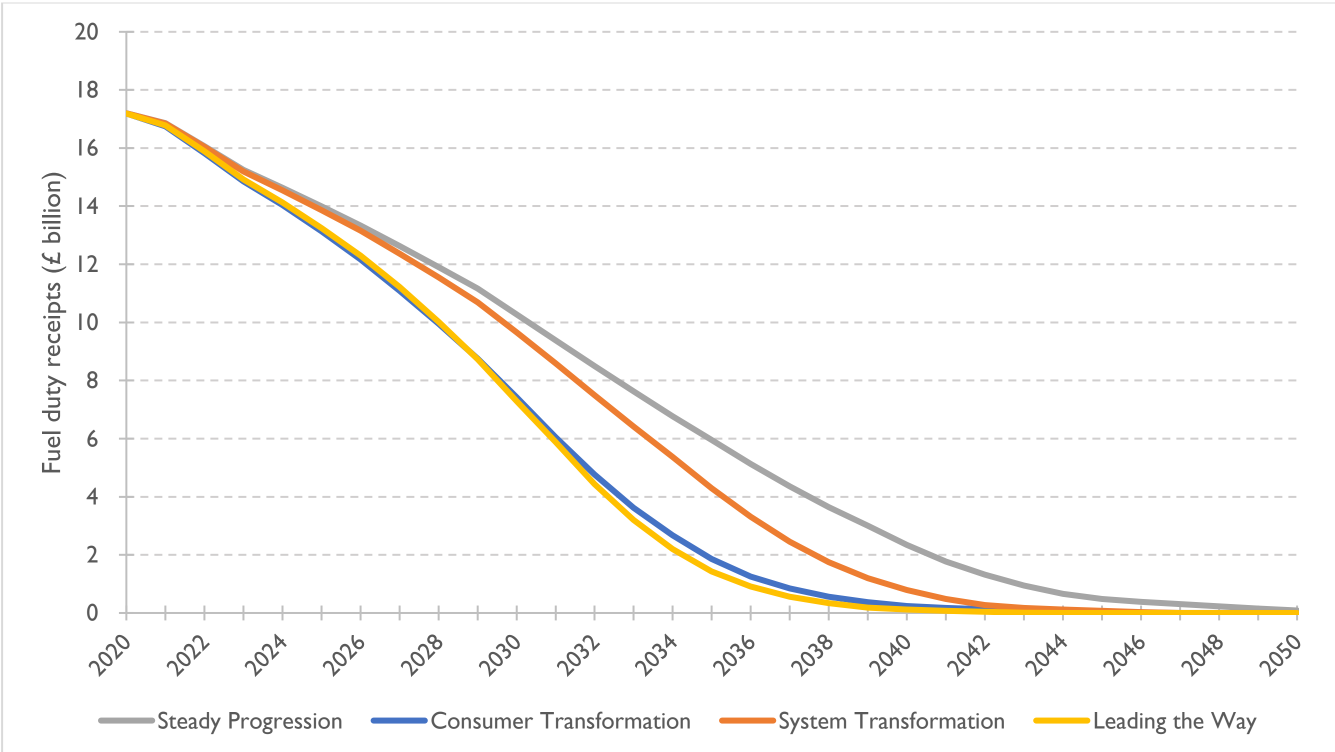

Figure 8: Fuel duty receipts from cars and vans (£ billion), 2020-2050, at 2020 prices, excluding the temporary reduction of 5 pence over 2022-24

Source: Own calculations as explained in the text

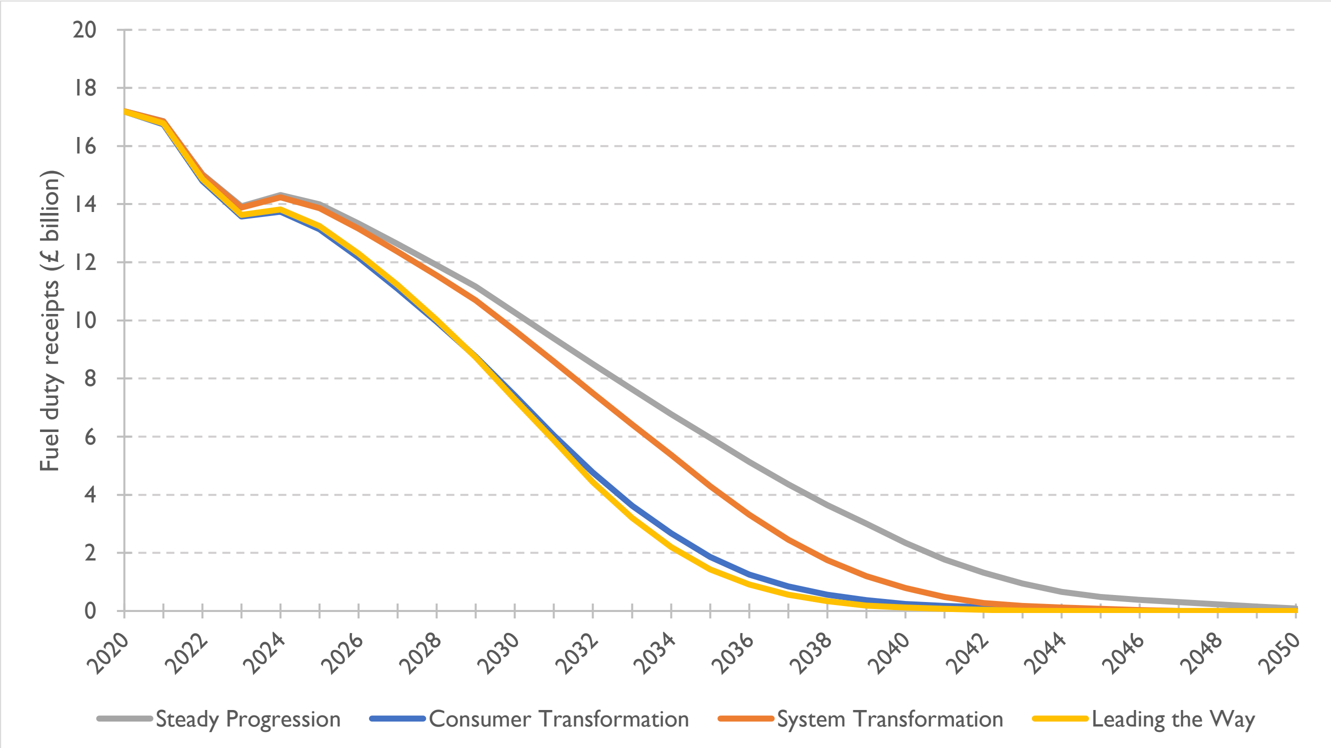

Figure 9: Fuel duty receipts from cars and vans (£ billion), 2020-2050, at 2020 prices, including the temporary reduction of 5 pence over 2022-24

Source: Own calculations as explained in the text

VAT receipts were calculated as 20% of fuel duty receipts from cars, not vans, as these were assumed to be working vehicles and get a VAT rebate, as explained in Section 3. Figure 10 shows the VAT revenues from fuel duties paid by cars under all scenarios at 2020 prices, including the temporary reduction in fuel duties over 2022-24.

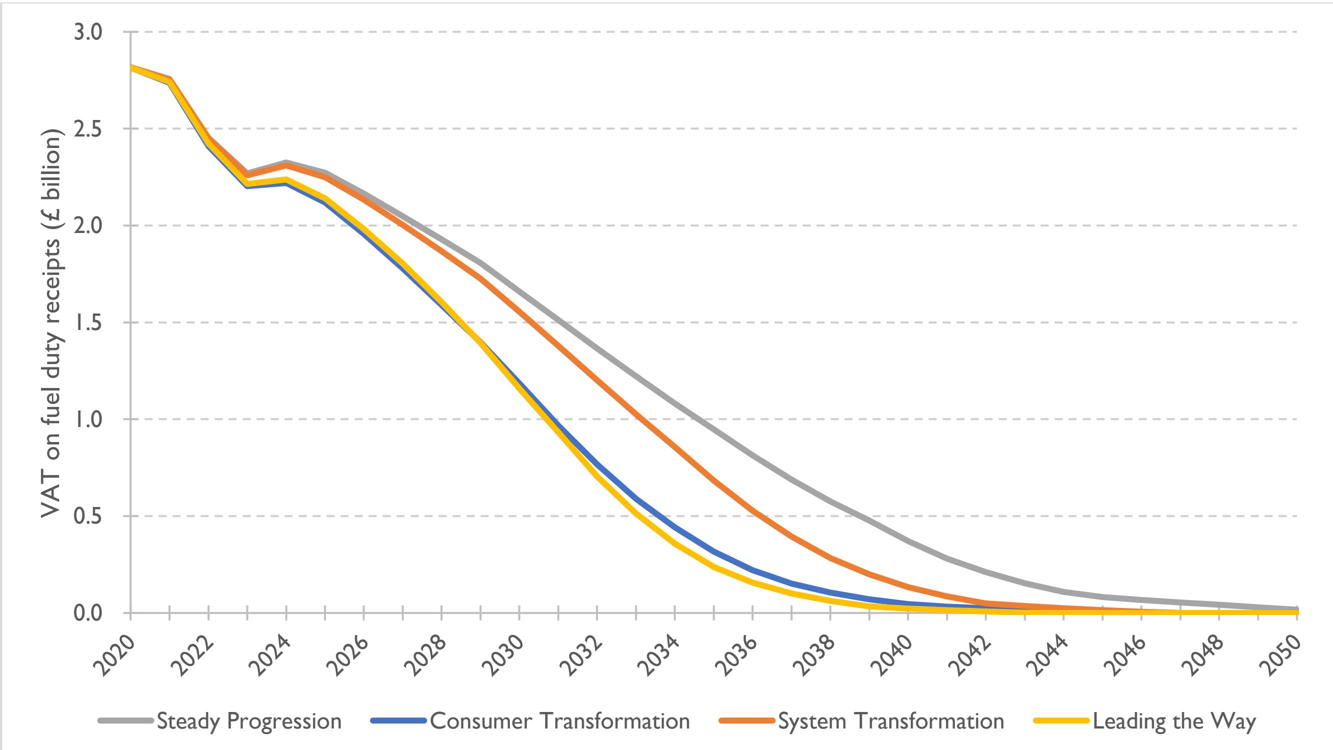

Figure 10: VAT on fuel duty receipts from cars (£ billion), 2020-2050, at 2020 prices, including the temporary reduction in fuel duties over 2022-24

Source: Own calculations as explained in the text

Clearly, the Leading the Way scenario, which is very ambitious in terms of decarbonization, is the most problematic in terms of government revenues from fuel duties paid by cars and vans, and VAT on fuel duty paid by cars. The Steady Progression scenario, on the other hand, sees revenues decrease at a slower rate, although by 2050 they are virtually zero.

Any forecast of GDP growth over a period of 30 years can only be taken as an indication as it is inherently subject to many assumptions about the future. Like the GDP deflator, the forecast used was taken from the Annual Parameters sheet of the TAG Data Book (Department for Transport, 2022b).

The ratio of revenues from fuel duty and VAT on fuel duty from cars and fuel duty from vans to GDP over the period 2020-2050 is presented in Figure 11.

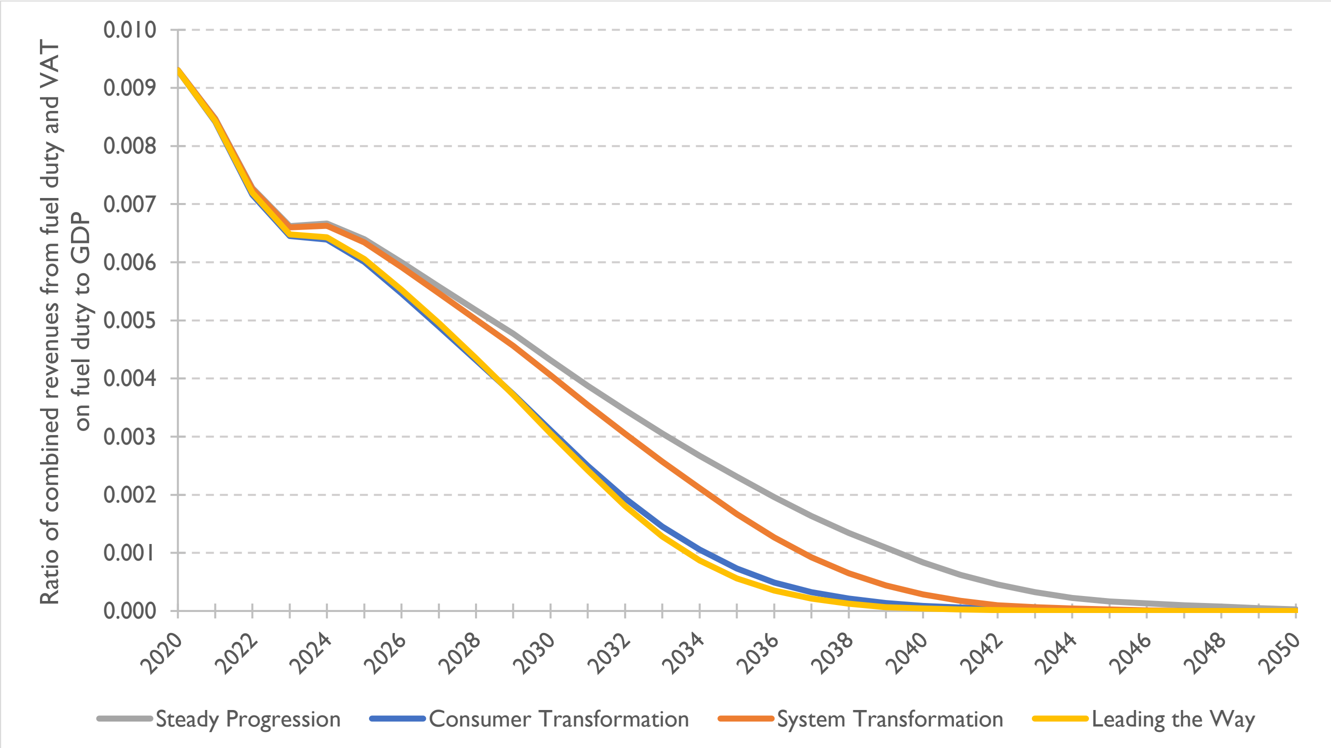

Figure 11: Ratio of combined revenues from fuel duty and VAT on fuel duty from cars and fuel duty from vans to GDP, 2020-2050, including the temporary reduction in fuel duties over 2022-24
Source: Own calculations as explained in the text

As it can be seen in Figure 11, receipts from fuel duties and VAT on fuel duties paid by cars and vans will decrease drastically relative to GDP, owing to the near or full electrification of the car and van fleet in the UK. As highlighted in Section 2, these substantial reductions are not exclusive to the UK. Studies for other regions of the world report declining revenues from motoring taxes due to electrification of road transport and predict a worsening of the problem in the future (Brady and O'Mahony, 2011; Jenn et al., 2015; Infrastructure Partnerships Australia, 2019; Davis and Sallee, 2020; Kolpakov and Sipiora, 2020; Hensher et al., 2021; Irish Parliamentary Budget Office, 2021; Meaker, 2021; Bonilla et al., 2022; Konstantinou et al., 2023).

The implications of this are obvious and require urgent action. This is the subject of the section that follows.

4.3 What next?

Revenues from fuel duty and VAT on fuel duty from cars and vans are set to erode by 2040-2050, depending on Government policies or in other words, scenario favoured.

Given the short time window to replace these revenues, the government should prioritize the phase-in of a new set of road taxes, which need to be designed as a matter of urgency. From a public acceptability point of view, it will be easier to reduce fuel duties drastically or even eliminate them and replace them with new taxes now than to wait until these disappear, by which time, the motoring public will have come to expect untaxed motoring (Adam and Stroud, 2019).

Swift action is warranted (Adam and Stroud, 2019) and it is vital that alternative sources of revenue are identified in the short to medium term. An additional problem the government faces, and which complicates policy design, is that many car models are still to reach cost parity (Santos and Rembalski, 2021). Despite that, the government stopped subsidies for plug-in cars in 2022, and refocused financial help towards public charging and subsidies to plug-in taxis, motorcycles, vans and lorries, and wheelchair accessible vehicles (Department for Transport et al., 2022). In addition, it announced that the vehicle excise duty paid by alternative fuel vehicles would be equalized with the vehicle excise duty paid by internal combustion engine vehicles from 2025 onwards (HMRC, 2022).

The trade-off that the government faces does not have an easy fix. The new set of road taxes could entail a new tax on electricity, or a road charge, or a distance-based charge, or some combination of those. Drivers of electric vehicles do not currently pay any taxes, except for VAT on electricity, at a reduced rate of 5% if the battery is charged at home, and introducing any of these ideas could act as a disincentive and slow down electric vehicle uptake.

A new tax on electricity would be difficult to implement, unless there was a way of differentiating between electricity used to charge the batteries of electric vehicles and electricity used for other purposes.

A road charge would apply to all vehicle types, regardless of whether they ran on fossil fuels or electricity, although the actual charge paid by different powertrains would be different. Efficient road pricing would entail the internalization of all externalities, including accidents, congestion, climate change, air pollution and noise. Electric vehicles do not cause any noise or tailpipe emissions, but they still cause non-tailpipe air pollution, accidents, and congestion. In fact, the costs of accidents involving an electric vehicle and an internal combustion engine vehicle can be higher than the costs of accidents involving only internal combustion engine vehicles because electric vehicles are heavier (Shaffer et al., 2021). A system of road charges could be adjusted over time, catering for different types of vehicles, such as electric versus fossil fuel, and big versus small, and the externalities they cause. Accident costs could be internalized with pay-as-you-drive insurance (Parry, 2005; Parry et al., 2007), and congestion costs could be internalized with charges varying with congestion levels (Newbery, 1990; Parry et al., 2014) and vehicle size (Santos, 2017). Potentially, there could be a surcharge for vehicles that run on fossil fuels. There are a number of technology options which are already available and reliable (Glaister, 2018).

National road pricing was considered in the early 2000s, with the Department for Transport commissioning a study on the feasibility of road pricing in the UK and publishing it in 2004 (Department for Transport, 2004). Two years later, the Eddington Report supported the concept: "The potential for benefits from a well-designed, large-scale road pricing scheme is unrivalled by any other intervention" (Eddington, 2006, p. 39). The idea, however, was eventually abandoned, mainly due to public opposition.

There is now a clear renewed interest in the idea (Glaister, 2018; Adam and Stroud, 2019; Butcher and Davies, 2020; Bose et al., 2021) not least because of the urgent need to replace the rapidly diminishing revenues from fuel duties and VAT on fuel duties. Although public opposition is usually perceived as the greatest barrier (Lindsey and Santos, 2020), pricing for the use of roads may not just be possible but also acceptable (Butcher and Davies, 2020), especially if drivers are accustomed to the idea before they stop paying any fuel duties (Adam and Stroud, 2019).

A distance-based charge is another option to recoup the declining revenues from fuel duties and VAT on fuel duties. This idea has been entertained for other countries (Jenn et al., 2015; Davis and Sallee, 2020; Kolpakov and Sipiora, 2020; Hensher et al., 2021; Wang and Miao, 2021; Konstantinou et al. 2023). A distance-based charge could differentiate by vehicle size, as lorries take more space and motorcycles take less space than cars and vans. Glaister et al. (2011) propose a series of distance-based charges for the UK, ranging from charges payable when using motorways, to charges payable when using any road, combined with reductions in fuel duty and vehicle excise duty. Offering a minimum number of free miles per year (King and King, 2017; House of Commons Transport Committee, 2022), could help some way with equity concerns (Bose et al., 2021; House of Commons Transport Committee, 2022), which are also common to road pricing. Another way of addressing equity issues would entail making concessions to vulnerable groups, such as people with restricted mobility (House of Commons Transport Committee, 2022).

A new tax on electricity, or a road charge, or a distance-based charge, or some combination of those, could be designed to be revenue-neutral. Although falling, the revenues from fuel duties and VAT on fuel duties are still substantial. Being revenue-neutral, the new system could be implemented as a replacement of fuel duties, which would make the concept more acceptable (Adam and Stroud, 2019). As revenues erode, revenue-neutrality will become more difficult.

5. Conclusions and policy recommendations

We have estimated fuel duty and VAT on fuel duty revenues from cars and vans in the UK under the Future Energy Scenarios from National Grid ESO (2021a; 2021b; 2021c) through to 2050. These are set to decrease under all scenarios due to the electrification of the car and van fleet. Under the fastest decarbonization scenarios, revenues will reach virtually zero by 2040, and under the slowest decarbonization scenarios, revenues will reach virtually zero by 2050. This drastic reduction in revenues poses an important problem for the Treasury.

Electrifying road transport is essential for decarbonization, but the price of doing so is the loss in revenues from fuel duties and VAT on fuel duties. Given the short period of time in question, a new system of road taxes needs to be designed and implemented urgently. This new system could replace fuel duties, and this would probably make it more acceptable than a set of additional charges. Also, if done soon, it would be possible to make it revenue neutral. As revenues erode, it will be very difficult, if not impossible, for the government to introduce a new system which is revenue neutral.

Letting revenues from fuel duty and VAT on fuel duty disappear before they are replaced will leave the Treasury with a temporary shortfall that will have implications for public expenditure. Worse yet, when the new system is brought in, there is likely to be discontent, if not backlash, from the motoring public.

Future lines of research include the modelling of alternative sources of revenue, and in particular, a distance-based charge in the UK.

Acknowledgements

This work was supported by the Engineering and Physical Sciences Research Council [EP/S032053/1].

Data availability

All the data used in this paper is freely available from various websites, as highlighted throughout the paper.

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