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THE INTERNATIONAL COUNCIL ON CLEAN TRANSPORTATION

Optimizing to the last digit: How taxes influence vehicle CO_2 emission levels

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Date: 16 October 2015
Keywords: CO_2 taxes, CO_2 standards, vehicle test procedures

1. Summary

In addition to vehicle CO_2 emission standards imposed at the European Union (EU) level, a number of EU member states have put in place tax incentives and other incentives to encourage consumers to buy more efficient vehicles. We were interested in seeing what effect those policies have had on CO_2 emissions specifically, hypothesizing that new vehicles would tend to cluster at the incentive points. To test that hypothesis we analyzed the patterns in the distribution of CO_2 emissions over time.

The results indicate a clear shift toward what might be called tax-optimized vehicles. The shift is not universal, since it would be impossible for manufacturers to optimize vehicle models for all the diverse array of taxation schemes among member states. Rather, the data suggests manufacturers seek to make vehicle CO_2 emissions as beneficial as possible in as many tax schemes as possible, within the limitations imposed by engineering potential and manufacturing costs. Consumers, for their part, clearly seem to be aware of the tax implications of new vehicle emissions, and are making decisions accordingly.

Superficially, this could be regarded as a success for fiscal and environmental policy. However, looked at more closely, it is problematic it two respects. First, it highlights the disadvantage of a sharp change in vehicle tax based on CO_2 emissions performance, as opposed to a more continuous rate of decline/incline: namely, that government may end up heavily subsidizing (by forgoing tax revenue) a very small decrease in vehicle CO_2. Second, viewed in the context of the substantial and growing amount of evidence that real-world vehicle CO_2 emissions are significantly higher than the official type-approval emissions on which taxes are based, it suggests the member states are giving significant and increasing tax subsidies to vehicles that do not actually further the public policy objectives of those subsidies — or at least do so to a lesser extent than they should.

2. Introduction

In 2009, the European Commission introduced mandatory CO_2 standards for new passenger cars.[1] Under the regulation, CO_2 emission levels are monitored and the results made publicly available. A monitoring report published annually by the European Environment Agency (EEA) provides fleet averages by EU member state and also by manufacturer.[2] In addition, the International Council on Clean Transportation (ICCT) regularly publishes aggregated fleet averages of emission levels and technical characteristics of new vehicles in the EU.[3]

The analysis described in this paper takes a different perspective, looking not at fleet average CO_2 emission levels but instead at patterns in the distribution of the CO_2 emission values. For this purpose, we focus on the last digit of the vehicle CO_2 emission figures and aggregate cars into bins according to the last digit of official CO_2 emissions (in g/km). For example, new cars with CO_2 emission levels of 89, 99, 109, 119, 129, … g/km are grouped into the "9" bin, and their total registration numbers for a particular year are summed.

For the analysis, we make use of an ICCT internal database covering the years 2001–2014. This links data from various sources, including type-approval registrations, car magazines, and manufacturers.[4] In comparison with the EEA dataset, it covers a longer period of time, as detailed vehicle fleet data from EEA is only available for the years 2010–2014.

Section 3 describes the distribution patterns observed at several levels: for the EU overall, by member state, by vehicle

1 Mock, P. (2014). *EU CO_2 standards for passenger cars and light-commercial vehicles*. Retrieved from: http://www.theicct.org/eu-co2-standards-passenger-cars-and-lcvs

2 EEA (2014). *Monitoring CO_2 emissions from passenger cars and vans in 2013*. Retrieved from: http://www.eea.europa.eu//publications/monitoring-co2-emissions-from-passenger

3 ICCT (2014). *European Vehicle Market Statistics Pocketbook*. Retrieved from: http://eupocketbook.theicct.org

4 For details, see ICCT (2014). *European Vehicle Market Statistics Pocketbook*. Retrieved from: http://eupocketbook.theicct.org

segment, and by manufacturer. Section 4 then analyzes the distribution patterns for a few selected member states in more detail to illustrate the link between member state taxation schemes and vehicle emissions. Section 5 concludes by pointing to some key policy implications.

3. Aggregated distribution patterns

This section summarizes the observed distribution patterns for the EU new cars' fleet by focusing on the aggregated results by CO_2 emission "last-digit-bin."

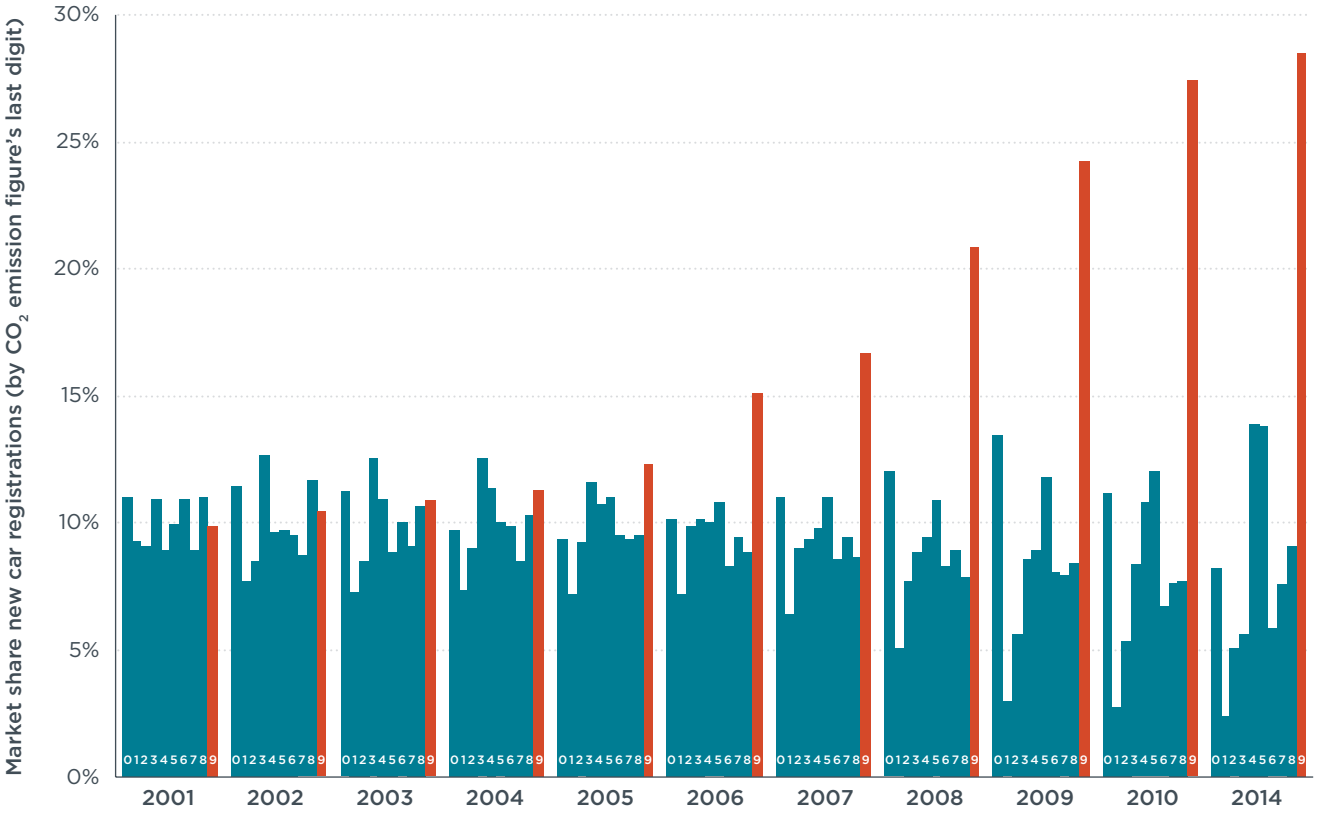

Figure 1. New car registrations in the EU, aggregated into CO_2 emission figure last-digit-bins, for the time period 2001–2014.

AT THE EU LEVEL

In 2001, CO_2 emission figures of new passenger cars in the EU were uniformly distributed, with all ten last-digit-bins accounting for about 10 percent of total registrations. Since 2006 a shift is noticeable, with the 9-bin becoming more common and the 1-bin in particular becoming more rare. In 2014, about 28 percent of new cars had a CO_2 emission figure ending with a "9", while only 2 percent of new cars had a figure ending with a "1" (Figure 1). Figure 2 focuses on the years 2001 and 2014 to highlight this effect.

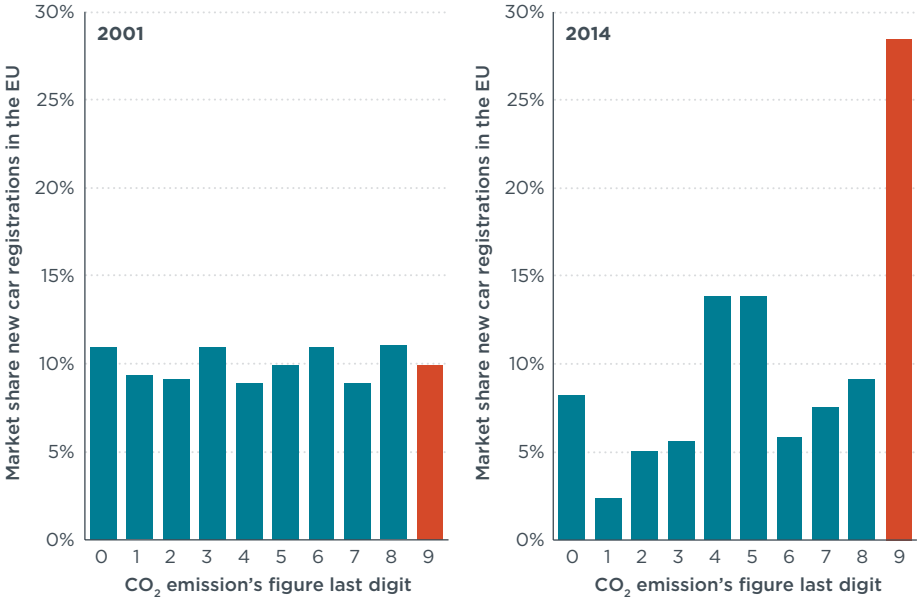

Figure 2. New car registrations in the EU, aggregated into CO_2 emission figure last-digit-bins, for 2001 and 2014.

AT THE MEMBER STATE LEVEL

For better visualization, the following charts focus only on those vehicles with a CO_2 emission figure ending with "9". In 2001, differences between member states were still small, with the probability of the last digit of a new vehicle's emission figure being "9" at around 10 percent. By 2014 this had changed drastically: not only is there now a higher share of vehicles in the 9-bin, but there are also large differences between member states. For example, in Luxembourg only 20 percent of new vehicles fall into the 9-bin, while this share is 36 percent in the UK (Figure 3).

AT THE VEHICLE SEGMENT LEVEL

The probability of a new vehicle being in the 9-bin is highest for the Upper Medium and Medium segments (34 and 33 percent) and lowest for the Luxury segment (14 percent) (Figure 4).

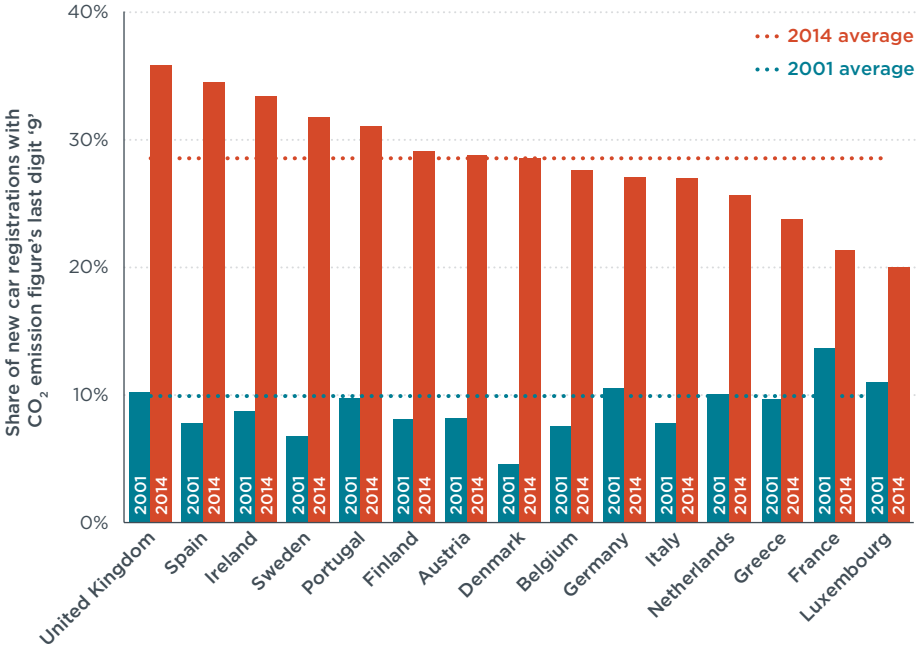

Figure 3. New car registrations in the EU with the CO_2 figure's last digit being 9, for 2001 and 2014 by member state.

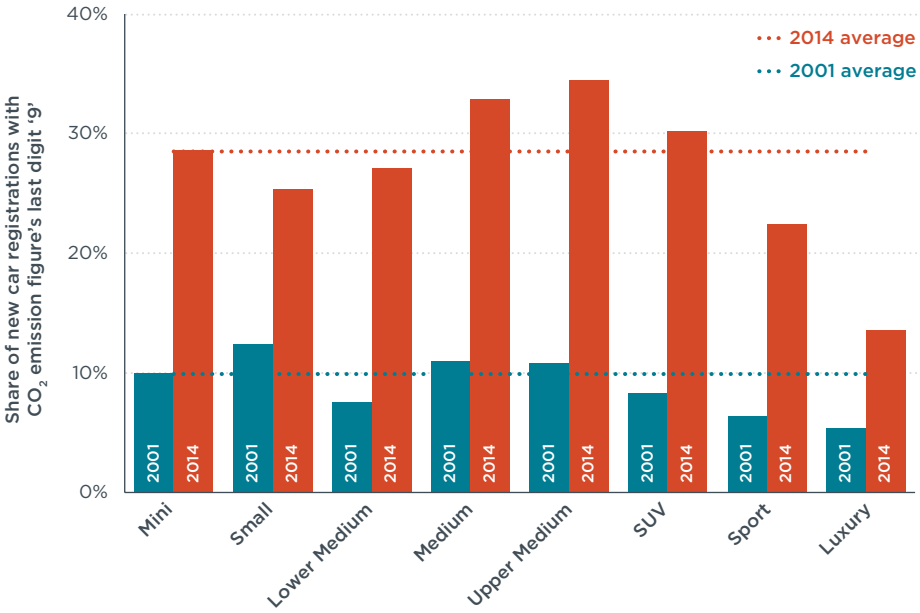

Figure 4. New car registrations in the EU with the CO_2 figure's last digit being 9, for 2001 and 2014 by vehicle segment.

AT THE MANUFACTURER LEVEL

With respect to individual manufacturers' brands, clear differences are visible. For example, while in 2001 only 6 percent of new Vauxhall vehicles had a CO_2 emission level ending with "9", this value increased to 49 percent in 2014 (Figure 5). Similarly, the probability of a vehicle being in the 9-bin is above average for Nissan, Mazda, Seat, Volvo, Ford, Opel and Audi. The change over time is less pronounced for VW, Peugeot, and Renault. In fact, the two French brands are the only ones where the share of 9-bin vehicles has decreased over time.

The previous charts showed the distribution of new vehicle *registrations*. Figure 6 affords a different perspective by showing the distribution of available model versions; i.e., every vehicle model/version that is on sale is counted and grouped by CO_2 emission last-digit-bin. While the ranking of brands is largely similar to Figure 5, the overall probability of a vehicle being in the 9-bin is slightly lower for the vehicle model/versions than for the vehicle registrations. In other words, there are market forces that are driving up the sales of 9-bin vehicles. This will become apparent when we analyze the distribution patterns by selected member states in Section 4.

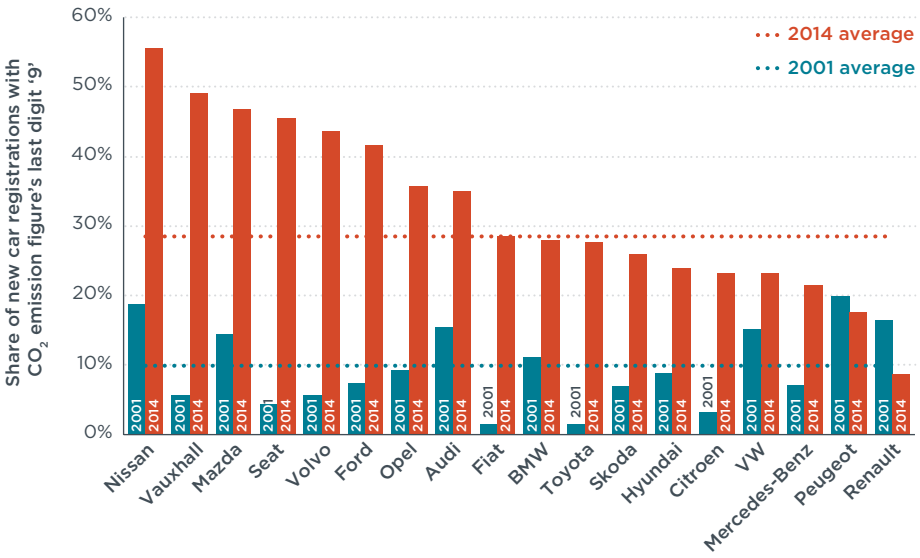

Figure 5. New car registrations in the EU with the CO_2 figure's last digit being 9, for 2001 and 2014 by manufacturers' brand.

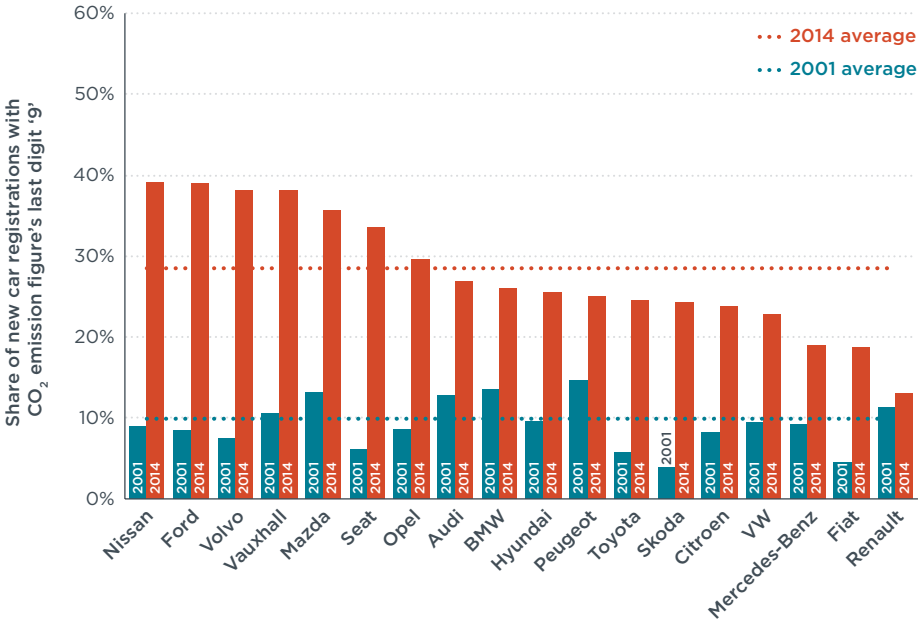

Figure 6. New car model model/versions in the EU with the CO_2 figure's last digit being 9, for 2001 and 2014 by manufacturers' brand.

4. Detailed distribution patterns by member state

In the following we analyze the new car fleet distribution for selected member states in more detail to point out how thresholds in taxation schemes can influence the CO_2 emission levels of new vehicles.

SPAIN

As shown in the previous section, Spain belongs to those member states where the probability of new cars' CO_2 emission levels ending with "9" is one of the highest in the EU. If we plot Spanish new car registrations in 2014, a spike at 119 g/km is particularly noticeable (Figure 7). More than 13 percent of all new cars registered in Spain in 2014 had a CO_2 emission level of 119 or 120 g/km. In fact, the new car fleet average for Spain in 2014 was also 120 g/km. This effect is most likely related to the fact that vehicles with CO_2 emissions up to 120 g/km are excluded from the one-time registration tax. For vehicles above 120 g/km, the tax is at least 4.75 percent of the vehicle price excluding VAT. Assuming a vehicle net price of €20,000, the tax benefit for a vehicle below 120 g/km therefore is €950. Another important tax threshold is at 160 g/km, at which level a 9.75 percent tax rate applies.

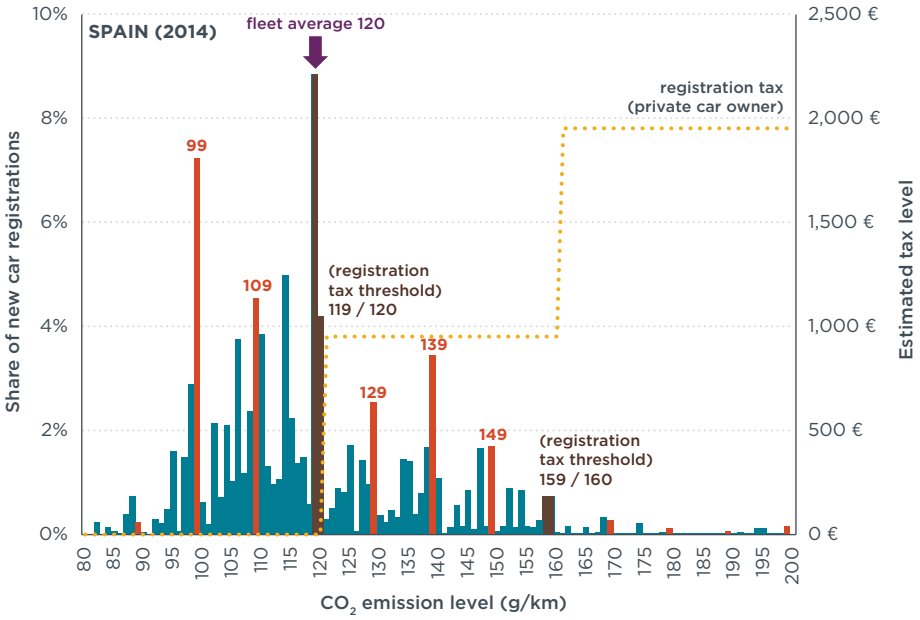

Figure 7. 2014 new car registrations in Spain by CO_2 emission level.

UNITED KINGDOM

The UK is another member state where the share of 9-bin vehicles is particularly high. Since 2001, registration and annual vehicle taxes are based on CO_2, with tax bands in 10 and 15 g/km steps. In 2014, new cars up to 100 g/km of CO_2 were exempt from the annual ownership tax. However, annual tax rates in the two next higher tax bands are only £20–£30. For vehicles with emissions higher than 130 g/km, the difference becomes more pronounced. Not only are they subject to an annual tax rate of

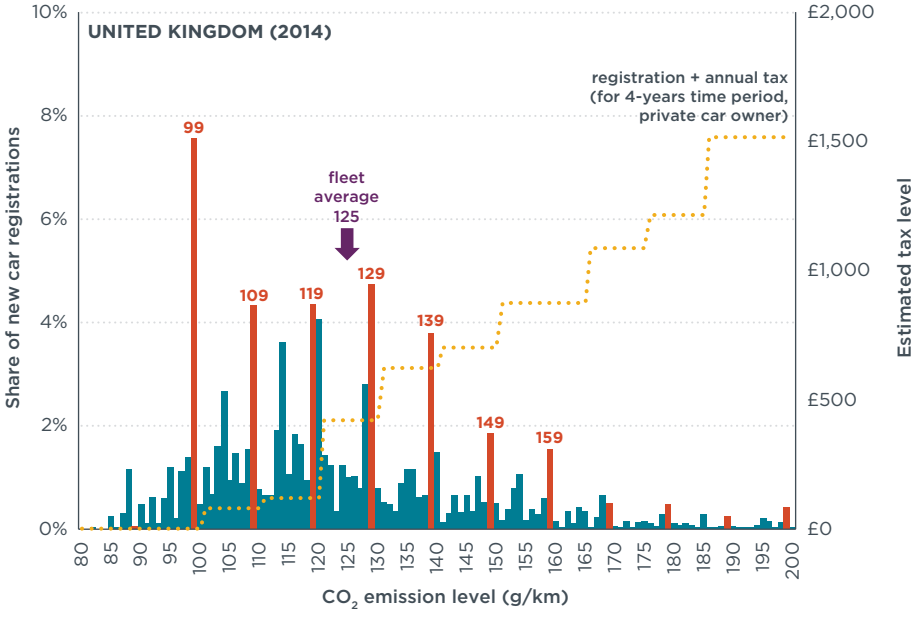

Figure 8. 2014 new car registrations in the UK by CO_2 emission level

£125, but also have to pay another £125 as a one-time registration tax. Looking at the vehicle CO_2 distribution, a general tendency towards the 9-bin can be observed, most likely related to the 10 g/km threshold steps (from 151 g/km on 15 g/km steps are used) for the car taxation scheme (Figure 8).

NETHERLANDS

The Netherlands is one of the member states with a lower share of 9-bin vehicles, as can be seen in Figure 3. And yet, when looking at the market distribution more closely, a clear spike at 99 g/km can be observed (Figure 9), as is also the case for other member states. Remarkable in the case of the Netherlands are the spikes for 85, 88, and 95 g/km. 85 and 88 g/km are the 2014 tax thresholds for the one-time registration tax (for diesel / petrol vehicles respectively).[5] For every g/km of CO_2 above these thresholds, an increasing tax rate applies. The financial impact of exceeding these thresholds can be very high; for example, the tax rate for a 130 g/km vehicle is around €4,500 (petrol) / €9,000 (diesel). Furthermore, 85 and 88 g/km are also the 2014 tax thresholds for company car taxation. This is an important factor in many European countries, including the Netherlands, where the majority of new cars are not registered to private owners but as company cars.

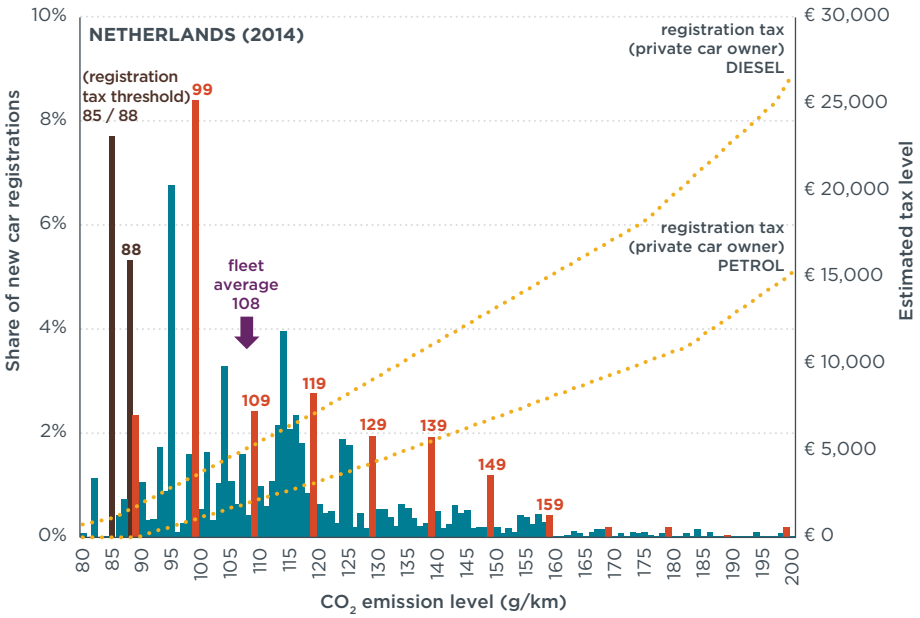

Figure 9. 2014 new car registrations in the Netherlands by CO_2 emission level.

5 The 95 g/km level was the corresponding tax threshold for petrol cars in 2013.

FRANCE

France is one of the markets where vehicle CO_2 emissions are most evenly distributed (Figure 10). The French bonus-malus taxation system provides an incentive for low-CO_2 emission vehicles. The bonus applies to vehicles below 61 g/km (below 111 g/km in the case of hybrid-electric vehicles), while all vehicles above 130 g/km need to pay a malus. Vehicles with a CO_2 emission level in between are subject to neither malus nor bonus. Company cars are taxed if their CO_2 emission level is above 100 g/km. Due to the structure of the French bonus-malus system, which has very little or no financial impact on the large majority of vehicles, most newly registered vehicles have a CO_2 emission level lower than 130 g/km but do not cluster around certain last-digit-bins. The only exceptions are the 129/130 g/km threshold, above which the tax rate steeply increases, and the psychologically important 99 g/km figure (as for all other member states examined in detail).

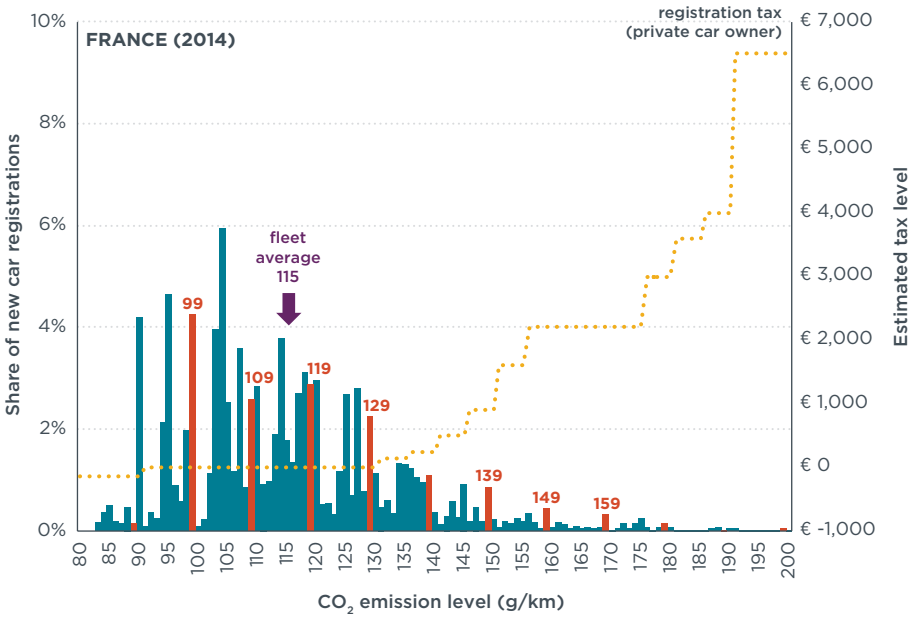

Figure 10. 2014 new car registrations in France by CO_2 emission level.

DEVELOPMENT OVER TIME

Spain and France illustrate the development of fleet structures over time. In Spain, the registration tax thresholds for 2014 were already in place in 2009. Therefore, when comparing the 2009 (Figure 11) and 2014 (Figure 7) fleet structures, it can be seen that the overall CO_2 average went down by about 15%, but at the same time the spike at 119/120 g/km remained mostly constant over time. Especially remarkable is the increase in the market share of vehicles with a CO_2 emission value of 99 g/km.

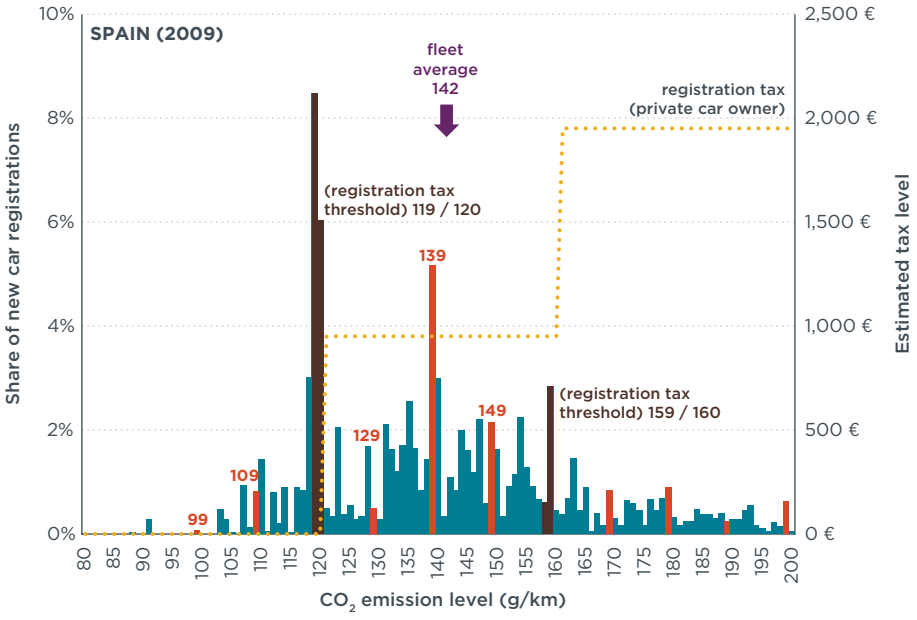

Figure 11. 2009 new car registrations in Spain by CO_2 emission level.

For France, on the other hand, the fleet structure in 2009 (Figure 12) is remarkably different than in 2014 (Figure 10). In 2009, there was still a major tax threshold at 120 g/km, with vehicles below that threshold receiving a €700 bonus. As a result, there is a clear spike around 119/120 g/km for France in 2009. From 2009 to 2014 the overall fleet average CO_2 emission level decrease by around 15%. However, the tax rate structure was adapted to the new fleet characteristics so that by 2014 most new cars in France are not subject to any bonus (or malus), and most of the clustering that was found in 2009 is gone.

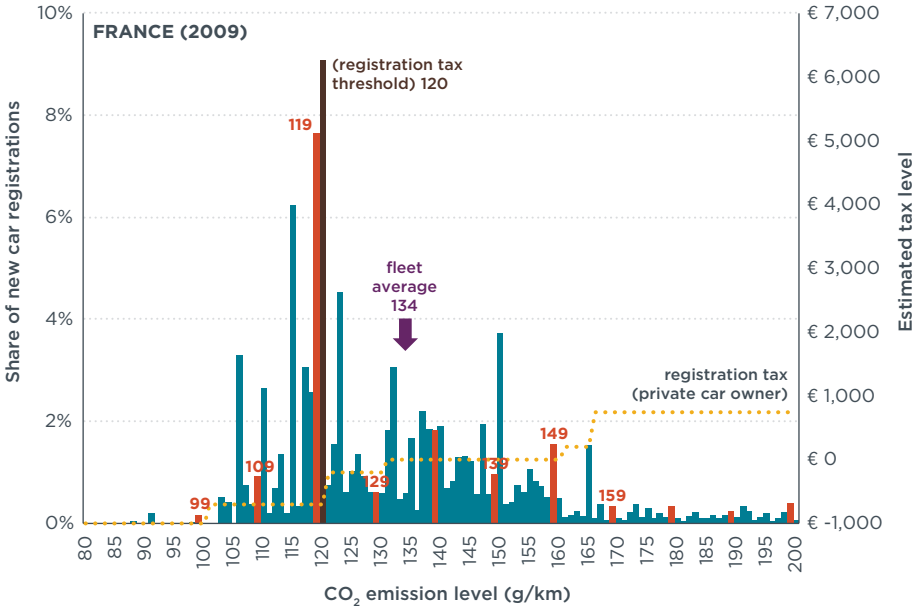

Figure 12. 2009 new car registrations in France by CO_2 emission level.

5. Conclusions and policy implications

This analysis has shown that there is a clear trend over time towards new vehicles with a CO_2 emission figure ending with "9". Member state vehicle taxation schemes are the most likely underlying explanation for this development. In some cases, a link between the taxation scheme and the vehicle registrations' share can clearly be identified (for example, in the case of the 119 g/km tax threshold in Spain). In other cases, an obvious link could not be found. For example, for all four member states examined in more detail, a high share of vehicles with 99 g/km of CO_2 was found, without a significant tax threshold set at this level.[6]

It also shows that for some member states there are notable spikes in the CO_2 figures' distribution for other last-digit-bins than the 9-bin. For example, in the Netherlands, due to thresholds in the vehicle taxation scheme, a high proportion of new cars have a CO_2 level of 85 or 88 g/km.

The distribution of new vehicle registrations by manufacturer resembles the distribution at member state level. For example, with Vauxhall focusing entirely on the UK market, it is not surprising to see a similar clustering of the brand's CO_2 emissions into the 9-bin as for the UK average. For Peugeot and Renault, both manufacturers with high market shares in France, a similar distribution as for the French market average was found. For vehicle segments, the most significant impact (i.e., the segments with the most 9-bin vehicles) was found for the Lower Medium and Medium segments, where there are generally most vehicles on the edge between two different tax categories and where it can make a significant difference whether the CO_2 emission level of a vehicle is one or two g/km higher or lower. For vehicles from the Luxury segment, on the other hand, the lowest impact was found. These vehicles tend to fall into high-CO_2 tax categories and in most cases it does not make a significant financial difference for the owner whether the vehicle's CO_2 emissions are slightly lower or higher.

Comparing the results for vehicle models on offer with consumer demand, the clustering around the 9-bin is slightly higher for the demand side, i.e., the vehicles chosen by consumers. This finding indicates that while vehicle manufacturers clearly know about the impact of vehicle taxation schemes and optimize their vehicle model range on offer accordingly, customers also know about their respective taxation schemes and tend to purchase vehicle models that are tax-optimized. It is also clear that vehicle manufacturers cannot optimize vehicle models for the taxation schemes of all EU member states at the same time. In reality, it is a compromise between making the vehicle's CO_2 emission level as attractive as possible in as many taxation schemes as possible, while also observing limitations on the engineering potential and cost side.

From a policy perspective, the observed developments are problematic in two ways. (1) If the tax level for a vehicle is significantly reduced because of a small change in CO_2 (to make it into the next lower tax category), that CO_2 reduction is relatively expensive

6 This is likely due to the psychological effect of two-figure vs. three-figure numbers, as described in more detail for example in: Thomas, M., Morwitz, V. (2005). *Penny Wise and Pound Foolish: The Left-Digit Effect in Price Cognition*. Journal of Consumer Research, Vol. 32, June 2005, p. 54-63.

from the government's perspective (foregoing significant tax revenues for a small reduction in CO_2). (2) If, in addition, the reduction in CO_2 is achieved by exploiting tolerances and flexibilities in the vehicle laboratory test procedure (in order to push a vehicle into the next lower CO_2 category), without any real CO_2 reduction in on-road driving, then this undermines policy objectives of mitigating climate change and reducing fuel costs for consumers. In that sense, because national vehicle CO_2 taxation schemes are so effective at steering CO_2 values, they can also accelerate the growing gap between official and real-world CO_2 emission figures.[7]

In order to avoid these unintentional effects, the best-practice recommendation for designing vehicle taxation schemes is to make use of a continuous tax rate function—that is, to avoid building in tax threshold steps.[8] That way, a clustering around certain CO_2 emission levels is avoided and the temptation to exploit loopholes in vehicle testing procedures is reduced.

7 For more details on the growing gap, see Mock, P. et al. (2014). *From laboratory to road: A 2014 update*. Retrieved from: http://www.theicct.org/laboratory-road-2014-update. See also Stewart et al. (2015). Quantifying the impact of real-world driving on total CO_2 emissions from UK cars and vans. Retrieved from: https://www.theccc.org.uk/publication/impact-of-real-world-driving-emissions/

8 For details, see German, J., Meszler, D. (2010). *Best Practices for Feebate Program Design and Implementation*. Retrieved from: http://www.theicct.org/best-practices-feebate-program-design-and-implementation