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Ex ante evaluation of the reform of company car taxation in Belgium

October 2022

Laurent Franckx, lf@plan.be

Rue Belliard 14-18 – Belliardstraat 14-18
1040 Brussels

e-mail: contact@plan.be
https://www.plan.be

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Federal Planning Bureau
Rue Belliard – Belliardstraat 14-18, 1040 Brussels
phone: +32-2-5077311
e-mail: contact@plan.be
https://www.plan.be

Ex ante evaluation of the reform of company car taxation in Belgium

October 2022

Laurent Franckx, lf@plan.be

Abstract - In Belgium, the Law on Fiscal and Social Greening of Mobility of 25 November 2021 eliminates corporate tax deductibility for all company cars except those with zero CO_2 emissions. In addition, the deductibility for electric company cars is reduced over time.

We have estimated the impact of these measures on fleet composition and tax and parafiscal revenues up to 2040 with the Belgian CAr Stock MOdel (CASMO).

The main effect of the tax reform is an accelerated electrification of the company car fleet and an accelerated decline in CO_2 emissions, peaking at about 1 million tons of CO_2 annually in the first half of the 2030s.

Compared to the no-reform scenario, the reform leads to an increase in net tax revenues of about 1 billion euro on an annual basis. Indeed, without the reform, the (autonomous) increase in the shares of gasoline PHEVs and electric cars in the company car market would lead to important foregone corporate tax revenues. This outweighs the decrease in income from other taxes, such as the excises on fuel consumption and the taxation of the benefit in kind in income taxes.

Abstract - En Belgique, la loi du 25 novembre 2021 organisant le verdissement fiscal et social de la mobilité du 25 novembre 2021 supprime la déductibilité de l'impôt des sociétés de toutes les voitures de société, à l'exception de celles dont les émissions de CO_2 sont nulles. En outre, la déductibilité des voitures de société électriques est réduite dans le temps.

Nous avons estimé l'impact de ces mesures sur la composition du parc automobile et les recettes fiscales et parafiscales jusqu'en 2040 avec le CAr Stock MOdel belge (CASMO).

Le principal effet de la réforme fiscale est une électrification accélérée du parc de voitures de société et une baisse accélérée des émissions de CO_2, avec un pic à environ 1 million de tonnes de CO_2 par an dans la première moitié des années 2030.

Par rapport au scénario sans réforme, la réforme conduit à une augmentation des recettes fiscales nettes d'environ 1 milliard euro sur une base annuelle. En effet, sans la réforme, l'augmentation (autonome) de la part des véhicules hybrides rechargeables à essence et des voitures électriques sur le marché des voitures de société entraînerait une perte importante de recettes fiscales de l'impôt des sociétés. Cette diminution du manque à gagner est plus importante que la diminution des recettes provenant d'autres taxes, telles que les accises sur la consommation de carburant et l'imposition de l'avantage toute nature dans les impôts sur le revenu.

Jel Classification - C25, H2, H3, Q58, R48
Keywords - company car taxation, tax reform, car demand, discrete choice modelling, car fleet greening, CO_2

Executive summary

In Belgium, the Law on Fiscal and Social Greening of Mobility of 25 November 2021 eliminates corporate tax deductibility for all company cars except those with zero CO_2 emissions. In addition, the deductibility for electric company cars is reduced over time.

While the new rules do not end the favorable income tax and parafiscal treatment of company cars, it is hoped that they will encourage an accelerated transition to an all-electric company car fleet.

To estimate the impact of these measures on fleet composition and tax and parafiscal revenues up to 2040, we compare two scenarios using the Belgian CAr Stock MOdel (CASMO) developed by the Belgian Federal Planning Bureau. The reference scenario is based on decided policies (except for the decided changes in company car taxation), namely the successive tightening of the low-emission zone in the Brussels-Capital Region and the planned European ban on placing cars emitting CO_2 on the market from 2035. In the scenario with tax reform, we also consider the changes resulting from the law of 21 November 2021. Both scenarios are based on the most recent World Energy Outlook of the International Energy Agency (IEA, 2021).

For our analysis, we assume that the rapid increases in market shares of electric and gasoline plug-in hybrid cars (PHEVs) observed in 2020-21 reflect a fundamental trend change that will continue in the future.

The tax reform accelerates the electrification of the company car fleet

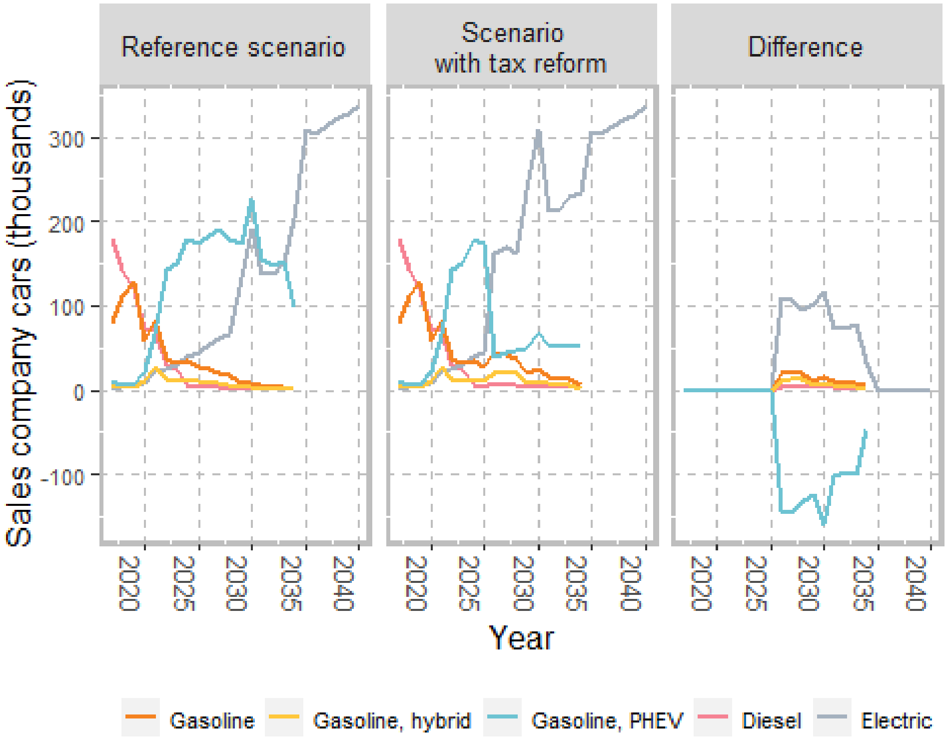
Our projections show that sales of gasoline PHEVs and of electric company cars will then grow rapidly, even without the tax reform for company cars. Initially, sales of gasoline PHEV grow faster than those of electric cars, reaching a market share of nearly 50% company cars by 2030. From 2028 onwards, sales of electric company cars grow faster and from 2029 onwards their market share even exceeds that of gasoline PHEVs.

At the same time, sales of diesel and gasoline cars are declining rapidly, and from 2030 gasoline PHEVs and electric cars completely dominate the company car market, with a total market share of over 85%.

The general ban on the sale of internal combustion engine cars within the European Union from 2035 has as obvious effect that, from that date on, only electric cars will be sold.

Compared to this scenario without tax reform, the main effect of tax reform is a very sharp decline in gasoline PHEV sales starting in 2026, mainly in favor of electric cars. The market share of electric company cars rises rapidly to above 50%, reaching more than 75% before 2030.

Graph 1 **Projections of the sales of new company cars with recalibrated categorical variables**



With the rapid renewal of the company car fleet, changes in the composition of sales also translate relatively quickly into changes in the composition of the fleet: by 2040 the company car fleet will be almost entirely electric, with or without tax reform. In other words, the tax reform mainly leads to an *acceleration* of the electrification of the fleet.

The accelerated electrification of the company car fleet leads to a decrease in tax revenues from the ownership and use of company cars compared to a scenario without reform

For the impact on tax and parafiscal revenues, we must consider that, from a tax standpoint, there are at least three categories of company cars:

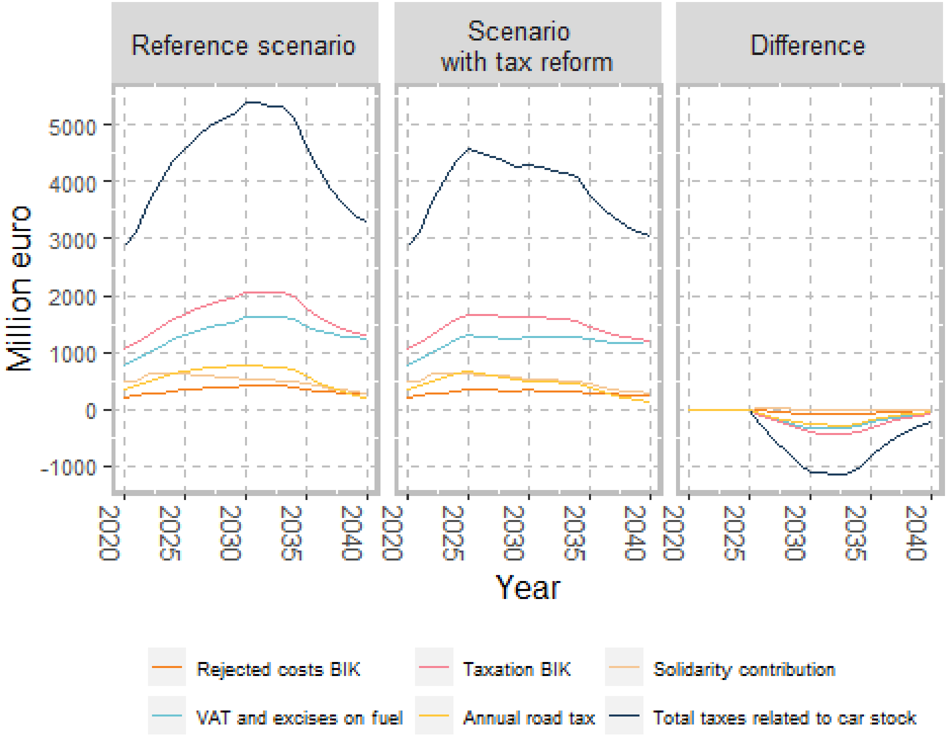
- All company cars benefit from a corporate tax deduction. In addition, company cars are subject to all the taxes to which cars owned by private individuals are also subject: vehicle registration tax, annual road tax, etc.
- All company cars used for private purposes without full reimbursement of these expenses by the user (the "salary cars in the broad sense of the word") are subject to a tax on the benefit in kind in the income tax. Part of the benefit in kind granted is additionally a non-deductible expense for corporate income tax purposes.
- Company cars offered to employees for private use without full reimbursement of these costs by the user (the "salary cars in the strict sense of the word") are additionally subject to an employer’s solidarity contribution to social security.

In presenting the results, we should also make the distinction between tax receipts determined by the ownership and use of company cars, and those resulting from the purchase of company cars.

The first category consists of (a) the indirect taxes on the consumption of fuel and/or electricity (b) the solidarity contribution to social security (c) the tax on the benefit in kind in the income tax (d) the non-deductible expenses for corporate taxation deductibility of the benefit in kind offered to employees (e) the annual road tax.

All these taxes depend on the total consumption of energy or on the CO_2 emissions per km of cars. Consequently, a faster electrification of the car fleet will lead to a decrease in these revenues. Around 2035, the total revenue foregone as a result of the tax reform peaks at around 1 billion euros, mainly due to lower revenues from the tax on the benefit in kind and from indirect taxes on fuel and electricity. Thereafter, the difference between the scenario with or without tax reform gradually decreases following the European ban on the sale of new cars with internal combustion engines.

Graph 2 **Projection of the tax revenues linked to the ownership and use of company cars**



The accelerated electrification of the company car fleet leads to higher corporate tax revenues compared to a scenario without reform

Regarding the taxes levied on the purchase of company cars, the deduction of car costs in corporate taxes is particularly important: the higher the deduction, the higher the revenue foregone for the government. In addition, the purchase of a car also involves the payment of a registration tax and VAT – we will discuss these in a later section, but here we will first deal with corporate tax deductions.

The expected sharp increase in sales of gasoline PHEVs in the years before the tax reform comes into force will lead to a significant increase in corporate tax revenue losses: from less than €1 billion per year in the current situation to more than €3 billion per year in 2030. Indeed, these cars enjoy a relatively large deduction due to their low CO_2 emissions. It should be noted though that the emission coefficients used for tax purposes are based on the test cycle, and emissions in real driving conditions can be significantly higher.

With a certain time lag, the foregone revenues as a result of the purchase of electric cars (which enjoy deductibility in corporate tax that decreases through time) will then also increase rapidly to more than 2 billion euros on an annual basis.

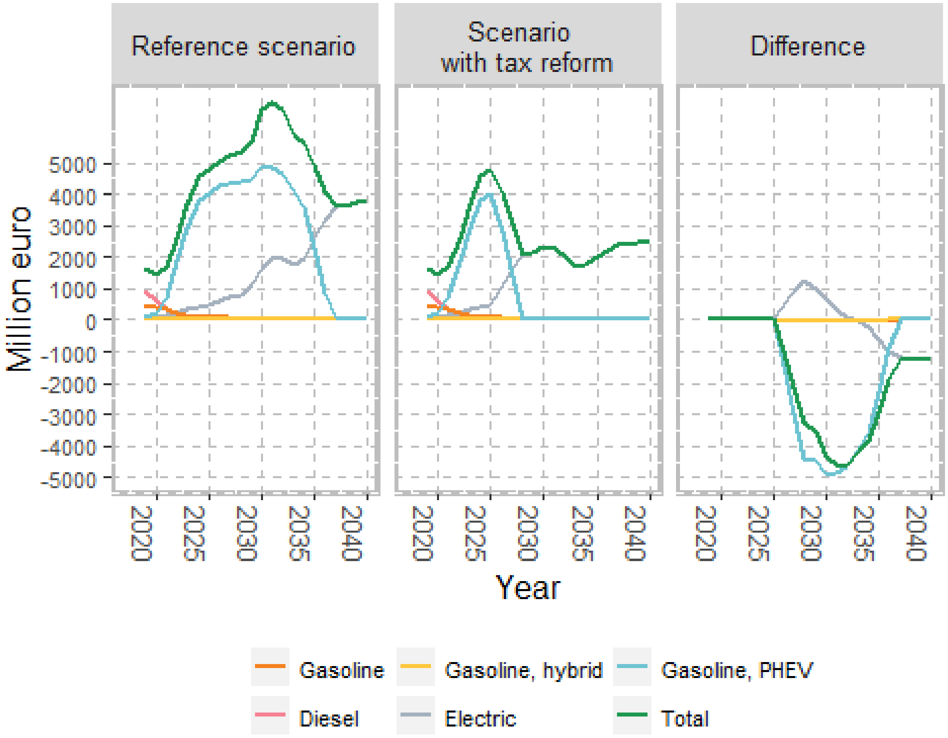
As a result of tax reform, the revenue foregone falls to zero for all car models (except fully electric models) starting in 2026.

For electric cars, however, the total effect on tax expenditures is not determined a priori: the per-car tax deduction decreases (leading to lower tax expenditures), but also entails increased sales of electric cars (leading to higher tax expenditures). In the first years of the reform, the second effect dominates, but this changes around 2030. After the European ban on the sale of new combustion engine cars has come into force, only the first effect remains. In the long run, as a result of the tax reform, lost revenues decrease by about 1 billion euros: in other words, corporate tax revenues increase by about 1 billion per year compared to a scenario without tax reform.

In the transition period between 2026 and 2035, the substitution of gasoline PHEVs by electric cars also plays a role. As a consequence, the additional revenues are much higher during that period, even peaking at almost 4 billion per year between 2030 and 2035.

However, the total revenue foregone after the reform still remains much higher than in the current situation, amounting to about 2.5 billion euros by 2040.

Graph 3 Projection of lost income in corporate tax due to deductibility of company car expenses



The accelerated electrification of the company car fleet has a net positive impact on public finances compared to a scenario without reform

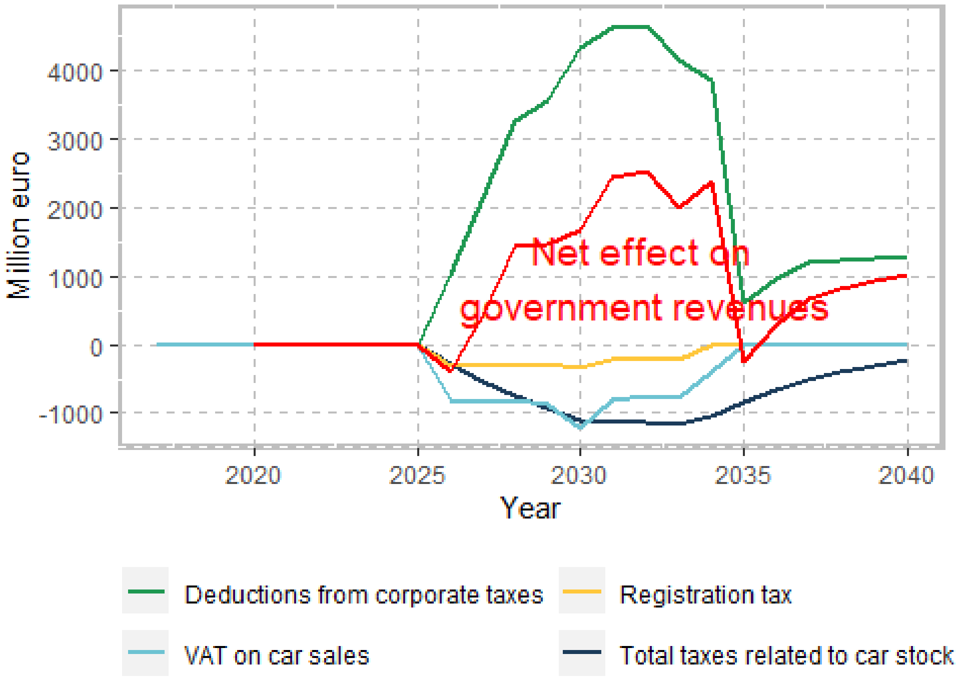
The reform also leads to a decrease in VAT receipts on car sales. Since VAT receipts are proportional to the purchase price of these cars, this means a shift towards cheaper car models.

The effect on revenue from the registration tax is very small. These effects are reduced to almost zero from 2035 onwards.

The net effects on public finances are summarised in Graph 4, in which we take the sum of the effects proposed in Graph 2 (taxes on car ownership and use) and Graph 3 (corporate tax deductions), respectively. In addition, we also present the impact on vat receipts and on the registration tax.

The overall effect of the reform is an increase in annual net tax revenues of about 1 billion on an annual basis beginning in 2026, except in 2026 and 2031, when the foregone revenues from the ownership and use of company cars slightly outweigh the increase in corporate tax revenues. Without the reform, the foregone corporate tax revenues would be much higher, due to the (autonomous) increase in the shares of gasoline PHEVs and electric cars in the company car market.

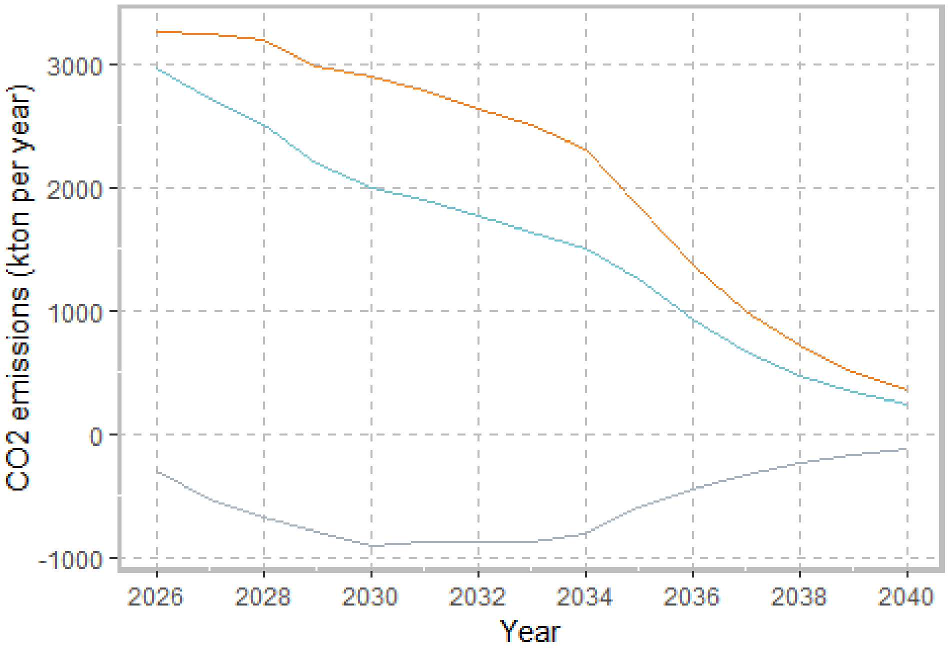
Graph 4 Net effect of the tax reform on tax revenues



The accelerated electrification of the company car fleet leads to an accelerated reduction in CO_2 emissions compared to a scenario without reform

Finally, we looked at the impact on CO_2 emissions from company cars. Due to the European ban on new internal combustion engine cars from 2035, the emissions of the company car fleet decrease very rapidly after 2034, both with and without reform. The major difference is in the years between 2026 and 2035, where the tax reform clearly leads to an accelerated decline in CO_2 emissions, peaking at about 1 million tons of CO_2 annually in the first half of the 2030s.

Graph 5 **Net effect of the tax reform on CO_2 emissions from the company car fleet**



Synthèse

En Belgique, la loi du 25 novembre 2021 organisant le verdissement fiscal et social de la mobilité du 25 novembre 2021 supprime la déductibilité de l'impôt des sociétés de toutes les voitures de société, à l'exception de celles dont les émissions de CO_2 sont nulles. En outre, la déductibilité des voitures de société électriques est réduite dans le temps.

Bien que les nouvelles règles ne mettent pas fin au traitement fiscal et parafiscal avantageux des voitures de société, on espère qu'elles encourageront une transition accélérée vers un parc de voitures de société entièrement électrique.

Pour estimer l'impact de ces mesures sur la composition du parc automobile et les recettes fiscales et parafiscales à l’horizon 2040, nous comparons deux scénarios au moyen du modèle belge CAr Stock MOdel (CASMO) développé par le Bureau fédéral du Plan.

Le scénario de référence se fonde sur les politiques décidées (à l'exception des modifications de la taxation des voitures de société), à savoir le renforcement progressif de la zone de faibles émissions dans la Région de Bruxelles-Capitale et l'interdiction européenne de mettre sur le marché des voitures émettant du CO_2 à partir de 2035. Dans le scénario incluant la réforme fiscale, nous prenons également en compte les changements résultant de la loi du 21 novembre 2021. Les deux scénarios sont basés sur le dernier World Energy Outlook de l'Agence internationale de l'énergie (IEA, 2021).

Notre analyse part de l’hypothèse que les augmentations rapides des parts de marché des voitures électriques et hybrides rechargeables (VHR) à essence observées en 2020-21 reflètent un changement de tendance fondamental qui se poursuivra à l'avenir.

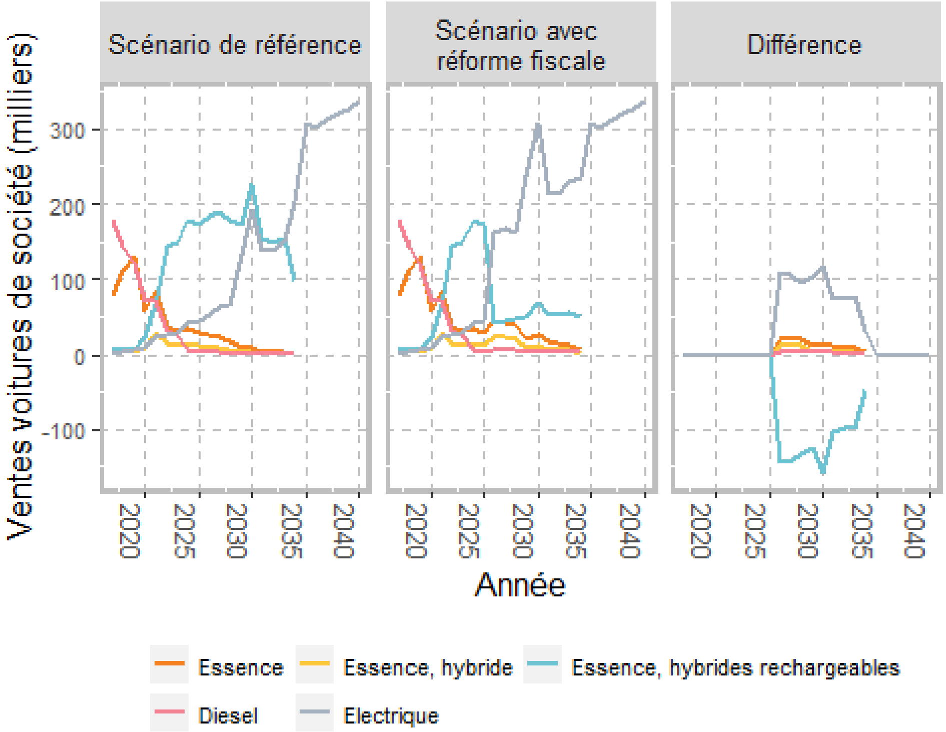
La réforme fiscale accélère l'électrification du parc automobile d'entreprise

Nos projections montrent que les ventes de VHR à essence et de voitures de société électriques vont croître rapidement, même hors réforme fiscale des voitures de société. Dans un premier temps, les ventes de VHR à essence augmentent plus rapidement que celles des voitures électriques, pour atteindre une part de marché de près de 50 % des voitures de société en 2030. À partir de 2028, les ventes de voitures de société électriques progressent plus rapidement et, à partir de 2029, leur part de marché dépasse même celle des VHR à essence.

Dans le même temps, les ventes de voitures diesel et à essence diminuent rapidement, et à partir de 2030, les VHR à essence et les voitures électriques dominent complètement le marché des voitures de société et occupent une part de marché totale de plus de 85 %.

L'interdiction générale de la vente de voitures à moteur à combustion interne dans l'Union européenne à partir de 2035 a pour effet évident qu'à partir de cette date, seules des voitures électriques seront vendues. Le principal effet de la réforme fiscale est une très forte baisse des ventes de VHR à essence à partir de 2026, principalement au profit des voitures électriques. La part de marché des voitures de société électriques augmente rapidement pour dépasser 50 % et atteindre plus de 75 % avant 2030.

Graphique 6 Projections des ventes de voitures de société neuves avec des variables catégorielles recalibrées



Compte tenu du renouvellement rapide du parc de voitures de société, les changements dans la composition des ventes se traduisent également assez rapidement par des changements dans la composition du parc en 2040, le parc de voitures de société sera presque entièrement électrique, que ce soit dans le scénario avec ou sans réforme fiscale. En d'autres termes, la réforme fiscale conduit principalement à une accélération de l'électrification du parc.

L'électrification accélérée du parc de voitures de société entraîne une diminution des recettes fiscales provenant de la propriété et de l'utilisation des voitures de société par rapport à un scénario sans réforme

Pour mesurer l'impact de la réforme fiscale sur les recettes fiscales et parafiscales, il faut tenir compet du fait que, du point de vue fiscal, il existe au moins trois catégories de voitures de société :

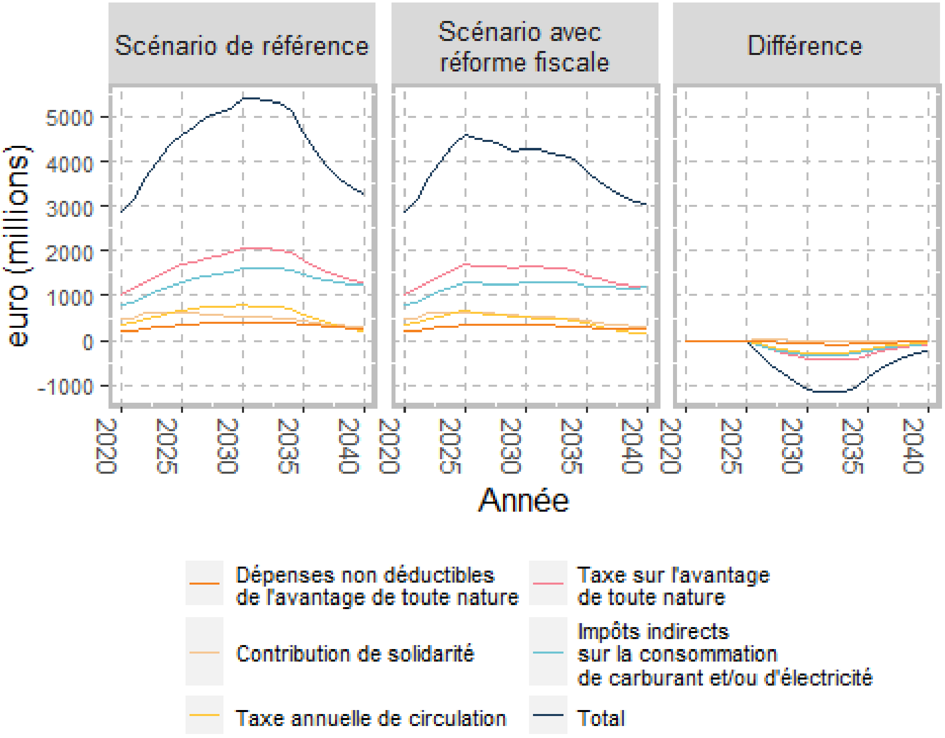
- Toutes les voitures de société bénéficient d'une déduction de l'impôt sur les sociétés. En outre, les voitures de société sont soumises à toutes les taxes qui s'appliquent aux voitures de particuliers : taxe de mise en circulation, taxe annuelle de circulation, etc.
- Les voitures-salaires au sens large, c'est-à-dire toutes les voitures de société utilisées à des fins privées sans remboursement intégral de ces frais par l'utilisateur donnent lieu à la taxation de l'avantage de toute nature à l'impôt des personnes physiques. Une partie de l'avantage de toute nature accordé constitue en outre une charge non déductible à l'impôt des sociétés.
- Les "voitures-salaires au sens strict"), les voitures de société offertes *aux employés* pour leur usage privé sans remboursement intégral de ces frais par l'utilisateur sont en outre soumises à une contribution de solidarité de *l'employeur* à la sécurité sociale.

Dans la présentation des résultats, il convient également de faire la distinction entre les recettes fiscales déterminées par la détention et l'utilisation de voitures de société, et celles résultant de l'achat de voitures de société.

La première catégorie comprend (a) les impôts indirects sur la consommation de carburant et/ou d'électricité (b) la contribution de solidarité à la sécurité sociale (c) la taxe sur l'avantage de toute nature dans l'impôt des personnes physiques (d) les dépenses non déductibles de l'impôt des sociétés de l'avantage de toute nature offert aux salariés (e) la taxe annuelle de circulation.

Toutes ces taxes dépendent de la consommation totale d'énergie ou des émissions de CO_2 par kilomètre des voitures. Par conséquent, une électrification plus rapide du parc automobile entraînera une diminution de ces recettes. Vers 2035, le manque à gagner total résultant de la réforme fiscale culmine à environ 1 milliard d'euros, principalement en raison de la baisse des recettes provenant de la taxe sur l'avantage de toute nature et des taxes indirectes sur le carburant et l'électricité. Par la suite, l'écart entre le scénario avec ou sans réforme fiscale diminue progressivement en raison de l'interdiction européenne de la vente de nouvelles voitures à moteur à combustion interne.

Graphique 7 **Projection des recettes fiscales liées à la possession et à l'utilisation de voitures de société**



L'électrification accélérée de la flotte de voitures de société entraîne une augmentation des recettes fiscales des entreprises par rapport à un scénario sans réforme

S’agissant des taxes liées à l'achat de voitures de société, la déduction du coût de la voiture dans l'impôt des sociétés est particulièrement importante: plus la déduction est importante, plus le manque à gagner pour le gouvernement est élevé. En outre, l'achat d'une voiture implique également le paiement de la taxe de mise en circulation et de la TVA – nous en parlerons dans une section ultérieure, mais ici nous traiterons d'abord des déductions de l'impôt des sociétés.

La forte augmentation attendue des ventes de VHR à essence dans les années précédant l'entrée en vigueur de la réforme fiscale entraînera une augmentation significative des pertes de recettes de l'impôt des sociétés : de moins de 1 milliard d'euros par an dans la situation actuelle à plus de 3 milliards d'euros par an en 2030. En effet, ces voitures bénéficient d'une déduction relativement importante en raison de leurs faibles émissions de CO_2. Il convient toutefois de noter que les coefficients d'émission utilisés à des fins fiscales sont basés sur le cycle d'essai, et que les émissions en conditions réelles de conduite peuvent être sensiblement plus élevées.

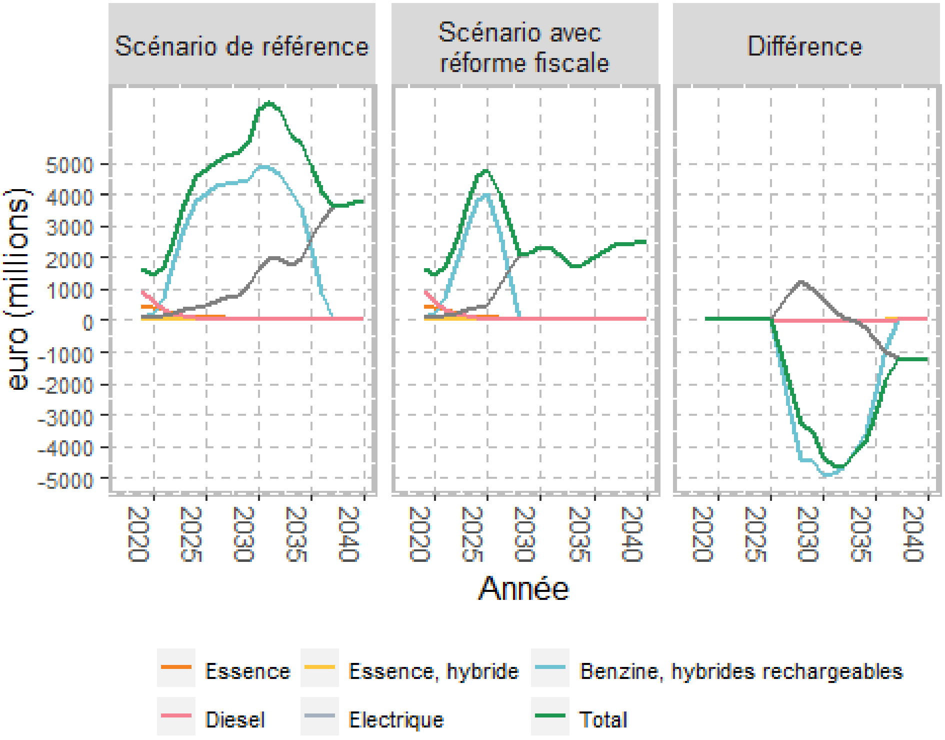
Avec un certain décalage dans le temps, le manque à gagner résultant de l'achat de voitures électriques (qui bénéficient d'une déductibilité de l'impôt des sociétés décroissante dans le temps) augmentera alors également rapidement pour atteindre plus de 2 milliards d'euros sur une base annuelle. À la suite de la réforme fiscale, le manque à gagner tombe à zéro pour tous les modèles de voitures (sauf les modèles entièrement électriques) à partir de 2026.

Pour les voitures électriques, cependant, l'effet total sur les dépenses fiscales n'est pas déterminé a priori : la déduction fiscale par voiture diminue (ce qui entraîne une baisse des dépenses fiscales), mais s’accompagne également d’une augmentation des ventes de voitures électriques (ce qui entraîne une hausse des dépenses fiscales). Dans les premières années de la réforme, le second effet domine, mais cela change vers 2030. Après l'entrée en vigueur de l'interdiction européenne de la vente de voitures neuves à moteur à combustion, seul le premier effet subsiste. À long terme, les recettes perdues suite à la réforme fiscale diminuent d'environ 1 milliard d'euros : en d'autres termes, les recettes de l'impôt des sociétés augmentent d'environ 1 milliard par an par rapport à un scénario sans réforme fiscale.

Dans la période de transition entre 2026 et 2035, le remplacement des VHR à essence par des voitures électriques joue également un rôle. Par conséquent, les recettes supplémentaires sont beaucoup plus élevées pendant cette période, atteignant même un pic de près de 4 milliards par an entre 2030 et 2035.

Toutefois, le manque à gagner total après la réforme reste encore beaucoup plus élevé que dans la situation actuelle et représente environ 2,5 milliards d'euros d'ici 2040.

Graphique 8 **Projection du manque à gagner de l'impôt sur les sociétés dû à la déductibilité des frais de voiture de société**



L'électrification accélérée du parc de voitures de société a un impact positif net sur les finances publiques par rapport à un scénario sans réforme

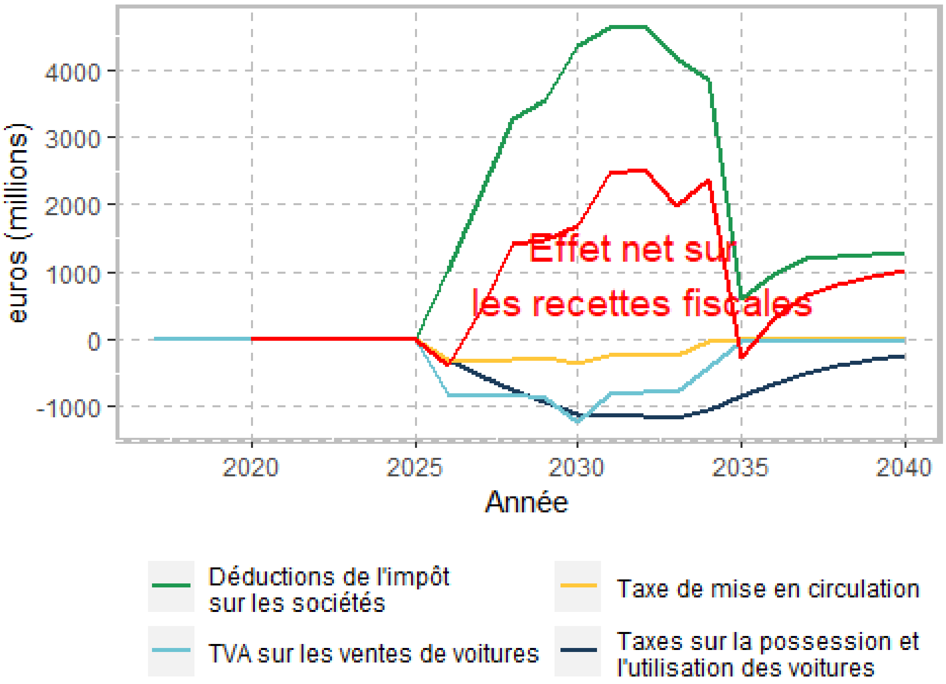
La réforme entraîne également une diminution des recettes de la TVA sur les ventes de voitures. Comme les recettes de TVA sont proportionnelles au prix d'achat de ces voitures, cela signifie un déplacement vers des modèles de voitures moins chers.

L'effet sur les recettes de la taxe de mise en circulation est très faible. Ces effets deviennent pratiquement nuls à partir de 2035.

Les effets nets sur les finances publiques sont résumés dans la Graphique 9 dans laquelle nous prenons la somme des effets proposés dans la Graphique 7 (taxes sur la possession et l'utilisation des voitures) et la Graphique 8 (déductions de l'impôt sur les sociétés), respectivement. En outre, nous présentons également l'impact sur les recettes de tva et la taxe de mise en circulation.

L'effet global de la réforme est une augmentation des recettes fiscales nettes annuelles d'environ 1 milliard sur une base annuelle à partir de 2026, sauf en 2026 et 2031, où le manque à gagner lié à la possession et à l'utilisation de voitures de fonction l'emporte légèrement sur l'augmentation des recettes de l'impôt sur les sociétés. Sans la réforme, le manque à gagner en matière d'impôt des sociétés serait beaucoup plus élevé, en raison de l'augmentation (autonome) de la part des VHR à essence et des voitures électriques sur le marché des voitures de société.

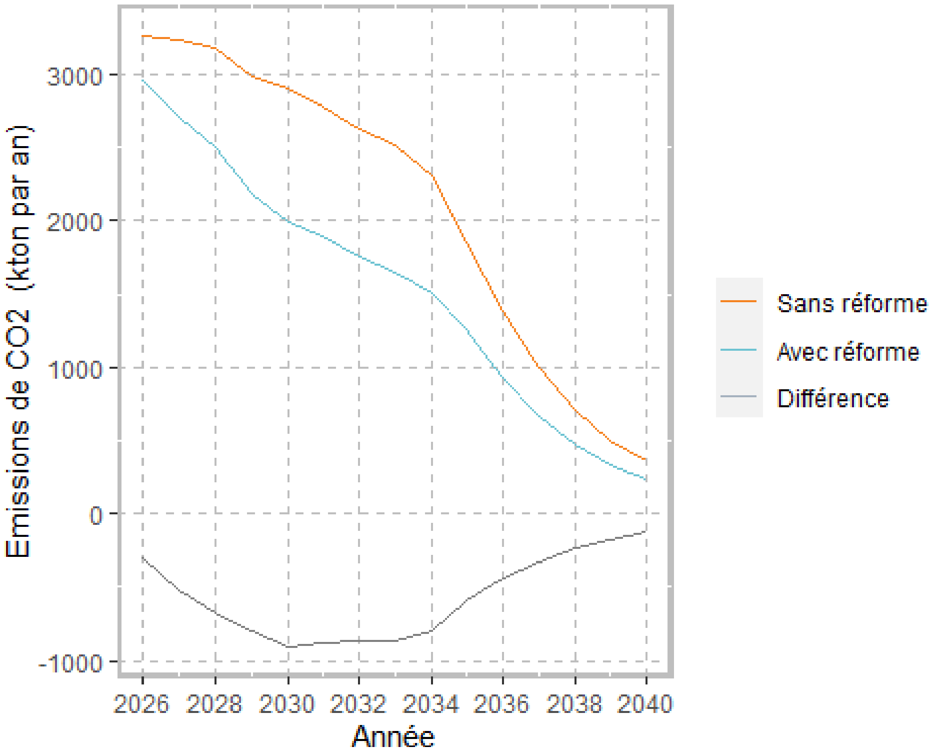
Graphique 9 **Effet net de la réforme fiscale sur les recettes fiscales**



L'électrification accélérée de la voiture de société accélère la réduction des émissions de CO_2 par rapport à un scénario sans réforme

Enfin, nous avons examiné l'impact de la réforme sur les émissions de CO_2 des voitures de société. En raison de l'interdiction européenne des nouvelles voitures à moteur à combustion interne à partir de 2035, les émissions du parc de voitures de société diminuent très rapidement après 2034, à la fois dans les scénarios avec et sans réforme. La principale différence se situe entre 2026 et 2035, années où la réforme fiscale entraîne clairement une baisse accélérée des émissions de CO_2, avec un pic d'environ 1 million de tonnes de CO_2 par an dans la première moitié des années 2030.

Graphique 10 Net effect of the tax reform on CO_2 emissions from the company car fleet



1. Introduction

In November 2021, several changes have been introduced to the Belgian tax code in order to stimulate the transition to a greener mobility system. [1] In this paper, we focus on one specific aspect: the changes in the fiscal treatment of company cars in corporate taxation.

The taxation of company cars, and its environmental and social impacts, has long been a controversial subject in Belgium. As in numerous other countries (Harding 2014), when employees in Belgium are allowed to use a company car for private trips, the estimated benefit-in-kind used for tax purposes is lower than the real cost of the car to the employer (Princen 2017). Moreover, in Belgium, both employees and employers are partially or completely exempt from social security contributions, and both the fixed and the variable costs of company cars are deductible under corporate income tax rules – we will describe this in more detail in Section 3.2.

The Law of 25 November 2021 phases out the corporate income tax deductibility for all cars except for zero-emission cars - we will assume that, in practice, this means fully electric ones. Thus, while the new rules do not put an end to the favourable treatment of company cars in the income tax system, it is hoped that they will stimulate an accelerated transition to a fully electric corporate tax fleet.

The reform does raise several questions:

- How strong is the incentive effect? The Belgian tax code already favours cars with low CO_2 emissions, but, until now, this has not lead to a strong uptake of electric cars.
- What will be the budgetary effect? One does not only have to take into account the direct effect on corporate taxes, but also (for instance) the income from excises on fuel consumption.
- Can we be confident that the substitution will be one from fossil fuel cars towards electric cars? What about hybrid cars or more fuel efficient cars with an internal combustion engine (ICE)?
- What about the interaction with other policies, such as future diesel and gasoline bans?

In order to answer these questions, we use the Belgian CAr Stock MOdel (CASMO) which has been developed by the Belgian Federal Planning Bureau.

The paper is structured as follows.

First, we briefly survey the existing literature on company car taxation. The two topics that are most discussed in the literature are the perverse behavioural incentives created by company car taxation and the foregone tax revenues as a result of the system. Some authors also raise the question whether company car taxation can be used to stimulate the transition to green mobility.

However, to the best of our knowledge, the current paper is the first to focus on the treatment of company cars in the corporate tax system rather than in the personal income tax system.

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[1] "Law on fiscal and social greening of mobility" of 25 November 2021

Second, we describe the CASMO model, which has been used for the current analysis. The core of CASMO consists of the integration of: (a) a sub-model that determines the total demand for cars (b) a sub-model that estimates, for each car purchased in the past, the probability that the car will change hands or be permanently scrapped (c) a sub-model that estimates the market share for each available car model. The components of the model are discussed in more detail later.

Third, we discuss all the taxes that affect the demand for company cars in Belgium. While it is impossible to discuss the relevant tax legislation in all its details, it is important to understand the numerous clauses in the Belgian tax system that already favour low CO_2 emission cars, including privately owned ones.

Fourth, we give an overview of all the assumptions we used regarding expected future policies, including European legislation, followed by the assumptions regarding the future evolution of new car, fuel and electricity prices.

We then proceed to describe the implementation of our results in CADMO. First, we look at the two models that we estimated statistically: the discrete choice model for the market shares of different cars in new purchases, and the so-called Markov process that describes how cars change owner types throughout their life cycle, and are eventually withdrawn from circulation. We also discuss how we estimated certain parameters to account for the sudden increase in market shares of electric and hybrid cars in 2020 and 2021. Finally, we describe in detail how CASMO uses these two statistical models to annually update the vehicle fleet.

Finally, we provide the results of our simulations. In doing so, we assume that 2020 and 2021 mark a trend change for the market shares of electric and hybrid cars.

In the appendices, we address a number of more technical points:

- a detailed description of the two main datasets used for the model estimation
- a technical discussion of the BLP approach for estimating discrete-choice models when only observations at the market level are available.
- a detailed theoretical rationale for the commercial vehicle cost indicators used in the discrete-choice model.

In addition, we also conducted two sensitivity analyses.

First, it is not certain that the sudden increases in the market shares of electric and hybrid cars in 2020-21 herald a new trend. We therefore also examined the impact of tax reform under the assumption that the observations in 2020-21 are only temporary changes, and that the market will return to “business as usual”. The impact of tax reform on tax revenues are broadly similar to what we obtain if we assumed a continuation of the 2020-21 trends.

Second, we looked at the impact of a slightly higher share of so-called “salary” cars in the total fleet of company cars.

2. Literature review

Most of the literature on the fiscal treatment of company cars dates from the two last decades - a rising interest which coincided with a steep increase in the number of company cars in most developed countries.

Using a survey held in 25 OECD countries, Harding (2014) estimated that the average share of company cars in total sales was around 19% – but this included outliers such as Canada and the US where the shares are below the 10%. In 20 of the countries included in the sample, the share exceeded 30%, and in 4 countries (including Belgium), it even exceeded 40%. More recently, Dataforce (2020) has estimated that the share of commercial registrations in the 8 largest EU car markets[2] has risen from 47.7% in 2007 to 56.4% in 2019.

The economic literature on this topic has emphasized the distortions that arise from taxing the in-kind benefit provided to the employee at a lower rate than other forms of labour income. These lower rates follow mostly from the combination of the following elements: (a) company cars are made available freely to the employee, but, for tax purposes, this benefit is usually not valued at the actual cost for the employer (b) the employee does not bear the variable costs (mostly, the fuel costs) associated with private car usage, even though the employer can deduct these variable costs from its taxable profits. Other sources of distortion (for instance, in Belgium) include the (partial or complete) exemption from social security contributions.

The literature has discussed the following behavioural distortions:

- The availability of a company car at the household levels increases the probability that the household owns an additional car (Börjesson and Roberts 2022, De Borger and Wuyts 2011, Gutiérrez-i-Puigarnau and van Ommeren 2011, Laine and Van Steenbergen 2016, Metzler et al. 2019, van Ommeren and Gutiérrez-i-Puigarnau 2013, Whelan 2007).
- Households with a company car also undertake more trips, have longer commutes and use public transport less often (De Borger and Wuyts 2011, Laine and Van Steenbergen 2016, Shiftan et al. 2012, Metzler et al. 2019).
- Company cars tend to be more expensive and heavier than privately owned cars (Gutiérrez-i-Puigarnau and van Ommeren 2011, Laine and Van Steenbergen 2016, Metzler et al. 2019).
- If fuel costs due to private car usage are reimbursed by the employer, the deductibility from corporate profits dilutes the incentives to reduce fuel consumption (Princen 2017).
- The favourable tax treatment of company cars leads to significant budgetary shortfalls that need to be compensated by higher (distortionary) taxes on other goods.

One limitation of studies measuring these effects is that it is difficult to account for self selection bias. For instance, if company cars are an instrument to avoid high marginal tax rates, they are most likely to be offered to employees who will buy a larger car anyway.

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[2] Belgium, France, Germany, Italy, Netherlands, Poland, Spain, United Kingdom.

With respect to Belgium, Harding (2014) has estimated the total annual subsidy per car at EUR 2 763 per year, which is the highest rate in the countries included in her study. She reckons that the total tax expenditure lies between 1500 and 2436 million EUR, with 1995 million EUR as a central estimate. Laine and Van Steenbergen (2017) estimate tax expenditures on the transport sector (including commuting subsidies) via the personal income tax system to be 1.9 billion EUR Finally, Princen (2017) reckons that the budgetary cost of the favourable tax treatment for company cars in Belgium accounts for EUR 3.75 billion of revenue foregone (0.9% of GDP in 2016) annually if one also includes the subsidy for fuel consumption.

The wide range of estimates for Belgium is due to the following elements: (a) while the Belgian national car registry keeps track of whether a car is owned by a legal entity or by a private person, it does not have a separate category for "company cars that are made available as a benefit in kind". As a result, the number of cars that benefit from the favourable tax regime is not known exactly, even though a lower bound can be obtained from social security data, as employers have to pay a "solidarity contribution to the social security system" for each company car made available to their employees. However, this figure does not include company cars that employers make available to themselves (b) in order to calculate the tax expenditure, one needs an estimate of the cost of the company car to the employer, which depends on elements such as the lifespan of the car, its value on the second hand market and the distance driven for private purposes. None of these elements are included in publicly available databases.

One element that gets an increasing share of attention is whether company car taxation can be used to stimulate the transition to green mobility – which is exactly the intention of the Belgian tax reform.

Dimitropoulos et al. (2014) have argued that the company car market can serve a diffusion channel for alternative fuel vehicles: "First, company car drivers do not have to incur (the usually high) upfront costs for the use of the AFV. Second, in the company car market the uncertainty about vehicle's resale price and operating costs is shifted from the car user to the employer or the car leasing firm." Using Swedish data, Engström et al. (2019) have confirmed that "private buyers were generally not prepared to accept the higher costs related to AFVs, and that they experienced a higher uncertainty in relation to the second hand value for these cars".

The ITF (2019) has pointed to two other important elements: "the high turnover rate of company cars results in fast adoption of new vehicle technologies. The high average annual usage of company cars also favours electric vehicles, as their running costs are typically lower than those of conventional vehicles."

Demeulenaere (2019) is somewhat sceptical, and points to findings that, just as private persons, fleet operators attach a disproportional weight to the upfront cost of a new vehicle, rather than to its total cost of ownership (TCO).

The current paper is a first step towards filling this gap in the literature.

3. The CASMO model: overview

3.1. Introduction

CASMO (CAr Stock Model) is a detailed model of the Belgian car fleet that has been developed within the Federal Planning Bureau since 2017 on the basis of the previous car fleet module of the PLANET model. The model can be used either independently or linked to the PLANET model.

A soft link to PLANET was used in the context of this project.

CASMO is structured as follows:

- The desired car fleet is calculated as a function of population and gross domestic product per capita.
- The probability of a car being withdrawn from circulation is calculated as a function of the age of the car. A separate survival function is estimated according to the emission class of the vehicle. The desired fleet is then compared with the remaining fleet, and this determines the total purchases of new cars in a given year.
- For the breakdown of total sales by emission class, we use parameters from a discrete choice model that calculates the probability of choosing a particular car model as a function of its technical characteristics and price.
- The output of the model is integrated into the car fleet, which is aggregated according to the emission class of the cars.

Since 2019, a number of important changes have been made to CASMO. The main features of the new version of the model can be summarized as follows (see Franckx (2019) for a detailed discussion of the previous version).

First, in the previous version of CASMO, we used a discrete choice model estimated from Dutch data, which was then calibrated to reflect the reality of the Belgian market in our reference period. In the new version of CASMO, the behavioral parameters were statistically estimated based on detailed purchase transactions in the Belgian market. These purchase transactions are taken from a database covering the whole period 2000-2019, and include data down to the level of individual car models, e.g. a BMW 320 2.0 gasoline with a maximum power of 135 kW and a weight of 2862 kg, or a Volkswagen T-Roc 1.5 gasoline with a maximum power of 110 kW and a weight of 1852 kg.

This database was purchased from IHS Markit Ltd – from here on we will refer to it as the “IHS database”.

The new discrete-choice model was estimated using the Berry-Levinsohn-Pakes algorithm, which is widely recognized as the reference model for this type of problem. The estimations took place using the BLPestimatoR library, which was written for the open source programming language R.

The combination of a detailed dataset with advanced econometric techniques allows realistic demand elasticities to be estimated.

A second important change is that the dataset with the purchase transactions was linked to a database of the European Environment Agency, which shows the CO_2 emissions for individual car models – for the recent years both according to the NEDC and the WLTP test cycle.[3] Based on this, the (theoretical) fuel consumption can also be estimated for cars with an internal combustion engine.

This allows not only to estimate the expected fuel cost of each individual car model, but also to calculate all tax parameters that depend on CO_2 emissions for each individual car model.

Third, using the database of the national vehicle registry (DIV), we can (approximately) break down the (national) purchase transactions according to the Region of registration, as well as the type of owner. In doing so, we can distinguish between natural persons, leasing companies and other legal entities.

Note that the data in these databases are not always filled in correctly or are mutually consistent. For example, the same model names are not always used in the different databases, so that a link between two databases always involves a number of manual corrections. In addition, errors sometimes occur in the assignment of the powertrain to individual cars - this is especially common with hybrid or plug-in hybrid cars.

Fourth, CASMO now takes into account a much wider range of fiscal parameters. The registration tax and the annual road tax are now calculated by Region for each individual model.

For the impact on tax and parafiscal revenues, we must consider that, from a tax standpoint, there are at least three categories of company cars:

- All company cars enjoy a corporate tax deduction. In addition, company cars are subject to all the taxes to which cars owned by private individuals are also subject: vehicle registration tax, annual road tax, etc.
- All company cars used for private purposes without full reimbursement of these expenses by the user (the "salary cars in the broad sense of the word") are subject to a tax on the benefit in kind in the income tax. Part of the benefit in kind granted is additionally a non-deductible expense for corporate income tax purposes.
- Company cars offered to *employees* for private use without full reimbursement of these costs by the user (the "salary cars in the strict sense of the word") are additionally subject to a employer’s solidarity contribution to social security.

The data from the DIV do not make it possible to distinguish between “pure” service cars and cars offered as a benefit in kind (henceforth referred to as “salary cars”).

However, it is possible to identify “salary cars” used by employees based on the solidarity contributions to social security due by the employers (see Section 3.2.6). A link between this data and that of the DIV was not possible within the time frame of this study, but may be considered in the future. The same holds for tax data, from which the number[4] of “salary cars” used by self-employed company managers can be derived.

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[3] See section 3.3.3 for more details on this.

[4] But not identity.

Based on consultation with the Belgian statistical office Statbel, in this analysis we assume that 59 percent of all company cars are salary cars.[5] Thus, for these cars, we need to consider not only their corporate tax treatment, but also the tax treatment of the benefit in kind and the solidarity contribution to Social Security. In the absence of data, we assume that all relevant characteristics of company cars are distributed in the same way among salary cars as among “pure” service cars.

Because the behavioral parameters in CASMO depend on these variables, it is also possible to calculate the effects of any alternative policies in any future follow-up projects.

CASMO allows grouping projections of the composition of the car fleet according to the following criteria:

- Engine type: diesel, petrol, electric, diesel hybrid, petrol hybrid, CNG, LPG, plug-in diesel hybrid, plug-in petrol hybrid
- CO_2 emissions: grouping according to the NEDC is possible for all vintages from 2010 onwards. WLTP is possible for the more recent vintages, as far as they are registered in the database of the European Environment Agency.
- Type of vehicle (passenger car, light truck)
- Cylinder capacity, battery size for electric vehicles and fiscal horsepower
- CASMO combines past fleet data with a statistical survival model to model the age structure (and thus the EURO class) of the future fleet.

We can also calculate emissions in real driving conditions using the COPERT methodology, which calculates emission factors for a number of classes determined by engine type and displacement.

However, it is not possible to identify "mild hybrid" cars based on the available data. As a matter of fact, the COPERT methodology does not include separate emission factors for this category because it is hardly distinguishable from cars with conventional internal combustion engines.

Fifth, we adapted the model to take into account the dynamics of the second-hand market.

Based on historical DIV data, we can distinguish in the existing car fleet between cars that are still in the possession of the first owner and cars purchased on the second hand market. However, the IHS database of purchase transactions only covers the market for new cars. Therefore, without price data, it is not possible to estimate a separate discrete choice model for the used market for CASMO.

We have been able to extend the simple survival model described above to include more choices: the choice is not purely between keeping a car in park and having it permanently scrapped, but is extended to the possibility of having it change the owner type. For example, we can calculate the probability that a leased car of a given age will be acquired by a private individual. However, when calculating these probabilities, we cannot take price data into account.

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[5] We perform a sensitivity analysis in Section 9.2 with a slightly higher value.

3.2. Existing taxes affecting company cars in Belgium

In this section, we describe the existing taxes that affect the demand for company cars in Belgium. Some of these taxes (the annual road tax and the registration tax) are not specific to company cars, and are also levied on cars owned by private persons. On top of this, we need to consider the treatment of company cars from the employees' perspective (income taxes and social security contributions) and from the employers' perspective (social security contributions, corporate taxes and VAT).

Note that this overview is not meant to be comprehensive, and that some complications have been skipped.

3.2.1. Annual road tax

The annual road tax is levied on all motor vehicles and their trailers. In this section, we focus on the regime for passenger cars that are not exempted because of their specific purpose (for instance, emergency vehicles).

In Belgium, setting the parameters of the annual road tax is a regional competence, except for leased cars, where the tax regime can only be modified with unanimity between the Regions.

Historically, the tariffs were based on the taxable horsepower of the car, and the Brussels and Walloon Regions have maintained this system. Table 1 presents the tariffs that were applicable in those Regions in the period 2015-2019 as a function of the taxable horsepower.

Table 1 **Annual road tax in het Brussels and Walloon Region**
In euro

Fiscal HP	cc	1 July 2014 till 30 June 2015	1 July 2015 till 30 June 2016	1 July 2016 till 30 June 2017	1 July 2017 till 30 June 2018	1 July 2018 till 30 June 2019
4	=<750	69.96	70.32	71.88	73.20	74.64
5	751-950	87.60	88.08	90.00	91.68	93.36
6	951-1150	126.48	127.20	130.08	132.48	134.88
7	1151-1350	165.36	166.20	169.92	173.04	176.28
8	1351-1550	204.48	205.56	210.12	214.08	217.92
9	1551-1750	243.60	244.92	250.32	255.00	259.68
10	1751-1950	282.24	283.80	290.04	295.44	300.84
11	1951-2150	366.24	368.28	376.32	383.40	390.36
12	2151-2350	450.24	452.76	462.72	471.36	479.88
13	2351-2550	534.00	537.00	548.88	559.08	569.28
14	2551-2750	618.00	621.48	635.16	647.04	658.80
15	2751-3050	702.00	705.96	721.56	735.00	748.32
16	3051-3250	919.56	924.72	945.00	962.64	980.16
17	3251-3450	1137.24	1143.60	1168.68	11190.52	1212.12
18	3451-3650	1354.80	1362.48	1392.36	1418.28	1444.20
19	3651-3950	1572.00	1580.88	1615.56	1645.68	1675.56
20	3951-4150	1789.68	1799.64	1839.24	1873.56	1907.64

In Flanders, the tariffs for cars that were registered before 2016 are very close to those tariffs. Table 2 presents the tariffs that were applicable in Flanders in the period 2015-2019 as a function of the taxable horsepower.

Table 2 Annual road tax in Flanders before environmental corrections
In euro

HP	1 July 2014 till 30 June 2015	1 July 2015 till 30 June 2016	1 July 2016 till 30 June 2017	1 July 2017 till 30 June 2018	1 July 2018 till 30 June 2019
4 and less	69.96	70.32	71.88	73.20	74.52
5	87.48	87.96	89.88	91.56	93.24
6	126.48	127.20	130.08	132.48	134.88
7	165.24	166.20	169.92	173.04	176.16
8	204.48	205.56	210.12	213.96	217.92
9	243.48	244.80	250.20	254.88	259.44
10	282.12	283.68	289.92	295.32	300.72
11	366.12	368.28	376.32	383.28	390.24
12	450.12	452.64	462.60	471.24	479.76
13	534.00	536.88	548.76	558..96	569.16
14	618.00	621.48	635.16	646.92	658.68
15	702.00	705.84	721.44	734.76	748.20
16	919.44	924.60	944.88	962.52	980.04
17	1137.24	1143.48	1168.68	1190.40	1212.12
18	1354.80	1362.36	1392.36	1418.28	1444.08
19	1572.56	1580.36	1615.36	1645.56	1675.44
20	1789.68	1799.52	1839.12	1873.32	1907.4
per additional HP above 20 HP	97.44	98.04	100.20	102.12	103.92

However, for cars registered after 1 January 2016, a double environmental correction applies in Flanders.

First, there is a correction for the CO_2 emissions. Until 2021, a surcharge of 0.3% was applied to the base tariff for each gram of CO_2 emissions per km above 122 gram per km and below 500 gram per km. A discount of 0.3% was applied for each gram of CO_2 emissions per km below 122 gram per km but above 24 gram per km. Since 2021, this threshold has been increased from 122 g CO_2 emission/km to 149 g CO_2 emission/km.

Second, there is a correction depending on the fuel, the EURO class and on whether the engine has a particle filter – see Table 3.

Table 3 Flanders: correction applied to the annual road tax according to fuel and Euro class

Euronorm	Diesel	Gasoline, LPG and natural gas
Euro 0	+50%	+30%
Euro 1	+40%	+10%
Euro 2	+35%	+5%
Euro 3	+30%	+0%
Euro 3 + particulate filter	+30%	Not applicable
Euro 4	+25%	-12.5%
Euro 4 + particulate filter	+17.5%	Not applicable
Euro 5 or EEV	+17.5%	-15%
Euro 6	+15%	-15%

Also, in Flanders an (indexed) minimum tax of 31.72 EUR applies to all cars.

Since 2016, all electric and fuel cell cars are exempted from the road tax in Flanders. This exemption also applies to PHEV cars that emit at the most 50 grams of CO_2 per km.

In the three regions, an additional tax is applied to cars that run on LPG.

Table 4 **Surtax for LPG cars**
In euro

Horsepower	SurTax
< 8 HP	89.16
8 to 13 HP	148.68
> 13 HP	208.20

In the three Regions, a 10% municipal tax is levied on top of the road tax.

3.2.2. Registration tax

The registration tax is applied to passenger cars that are purchased in Belgium - including on the second hand market. As was the case with the annual road tax, some cars are exempted because of their specific purpose (for instance, emergency vehicles). This will not be discussed here.

Here as well, since 2016, the Regions can determine the parameters of the tax, except for leased cars where the tax regime can only be modified with unanimity between the Regions.

In the Brussels and Walloon Regions, the tax is still determined by a car's fiscal horsepower and power expressed in kW. Table 5 represents the tariffs for newly purchased cars. When there is a conflict between the amount based on the HP and the amount based on the kW, the highest tariff applies. For cars that drive (even partially) on LPG, there is a deduction of 298 EUR.

Table 5 **Registration tax in the Brussels and Walloon Region**

PK	kW	2015 (in euro)
0-8	0-70	61.5
9-10	71-85	123.0
11	96-100	495.0
12-14	101-110	867.0
15	111-120	1239.0
16-17	121-155	2478.0
>17	>155	4957.0

The Walloon Region also applies a so-called "ecomalus", a surcharge that varies according to a car's CO_2 emissions. Cars that emit 145 gr CO_2 per km or less, are exempt from the ecomalus. For cars that emit more, the Ecomalus gradually increases from 100 EUR to a maximum of 2500 EUR (for cars emitting 255 gr or more).

In Flanders, the system is more complex. The following formula applies

$$\text{Registration tax in euro} = \left(\left((CO2 * f + x)/D\right)^6 * 4500 + c\right) * LC$$

where:

- D = 250 in 2015, and 246 as from 2016;
- f = 0.88 for LPG cars, 0.744 for dual fuel CNG-gasoline cars and 1 for all other cars;
- x (correction term for technological change) = 13.5 per gr of CO_2 per km in 2015 (increases with 4.5 per year)

- LC: correction for age - given that we consider only newly purchased cars in this analysis, LC = 100
- c: correction term for air quality, that depends on the fuel and Euro norm for the car - the values are given in Table 6 and Table 7.

Table 6 **Registration tax air quality correction term for diesel cars**
In euro

Euronorm	1 July 2014 till 30 June 2015	1 July 2015 till 30 June 2016	1 July 2016 till 30 June 2017	1 July 2017 till 30 June 2018	1 July 2018 till 30 June 2019
0	2223.94	2863.15	2926.14	2980.54	3034.65
1	652.47	840.00	858.48	874.44	890.32
2	473.30	493.36	636.27	648.10	659.86
3	372.93	467.06	504.21	513.59	522.91
4	352.49	467.06	477.34	486.21	495.04
5	346.50	459.35	469.34	478.12	486.87
6	12.79	545.07	464.04	472.69	481.27

Table 7 **Registration tax air quality correction term for gasoline, LPG- and CNG cars**
In euro

Euronorm	1 July 2014 till 30 June 2015	1 July 2015 till 30 June 2016	1 July 2016 till 30 June 2017	1 July 2017 till 30 June 2018	1 July 2018 till 30 June 2019
0	884.54	1138.78	1163.83	1185.47	1206.99
1	395.58	509.28	520.48	530.16	539.79
2	118.29	152.29	155.64	158.53	161.41
3	74.21	95.53	97.63	99.45	101.25
4	17.81	22.93	23.43	23.87	24.30
5	16.02	20.61	21.06	21.46	21.84
6	16.02	20.61	21.06	21.46	21.84

In Flanders, there is also a lower bound of 41.76 and an upper bound of 10439.45 EUR to the registration tax (values for 2015, indexed annually).

In 2021, the formula for the registration tax for newly registered cars in Flanders has been changed to:

$$\left((CO2 * f * q)/246\right)^{6} * 4500 + c) * LC$$

q is equal to 1.07 in 2021 and will be increased annually by 0.035 from the year 2022 onwards.

The minimum and maximum amounts continue to apply and are indexed annually.

Electric cars are exempted from the tax. Until 2021, this exemption also applied to cars with CNG engines and PHEV that emit at most 50 gr of CO_2 per km (until 2015, all PHEV were exempted).

Table 8 **Registration tax correction term as from 2021**

Euronorm	Diesel	Gasoline and other fuels
0	3106.80	1235.69
1	911.48	552.62
2	675.55	165.25
3	535.34	103.66
3 + particulate filter	506.81	Not applicable
4	506.81	24.88
4 + particulate filter	498.44	Not applicable
5	498.44	22.36
6	492.71	22.36

3.2.3. End of exemption for CNG and PHEV cars in Flanders

Natural gas vehicles with a maximum of 11 fiscal horsepower or plug-in hybrid vehicles with maximum emissions of 50 g CO_2 that are registered as from 1 January 2021 will no longer be exempt from annual road tax and the registration in Flanders. Vehicles registered on or before 31 December 2020 remain exempt from the annual road tax as long as they remain registered to the same owner. It does not matter whether they are new or second-hand vehicles.

3.2.4. Income taxes and corporate profit taxes

Until 2014, there was an income tax deduction for electric cars equivalent to 30% of the purchase price.

For company cars, the deduction in corporate tax depends on the nature of the expenses. For fuel costs, the deduction is set at 75%. For all other expenses, the corporate tax deduction depends on the CO_2 emissions of the car and on the fuel. Table 9 gives the deduction percentage for diesel and gasoline cars. For electric cars, the deduction percentage is 120%.

Table 9 Percentage corporate tax deduction as a function of CO_2 emissions.

CO_2 (g/km) - diesel cars	CO_2 (g/km) - gasoline cars	Deduction percentage
0-60	0-60	100
61-105	61-105	90
106-115	106-125	80
116-145	126-155	75
146-170	156-180	70
171-195	181-205	60
195-	205-	50

If the employer makes the company car (partially or completely) freely available for private use by the employee (“salary car”), then part of the benefit in kind[6]. (BIK - see below) that results from personal use is considered as rejected expense[7] (VU) for corporate tax purposes.

From 2013 to 2017, car expenses were considered as rejected expense at the rate of 17% of the benefit in kind arising from the personal use of a vehicle provided by the employer.

Since 2018, car expenses are included in the rejected expense at:

- 17% of the taxable amount of the benefit in kind if the employer does not reimburse fuel costs associated with the personal use of the vehicle;
- 40% of the taxable amount of the benefit in kind if the employer reimburses fuel costs associated with the personal use of the vehicle (even if only partially);

Due to lack of data on the proportion of personal use, we have always assumed 40%.

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[6] A benefit in kind is a benefit that an employer or company grants to an employee or manager and that is considered professional income

[7] This is defined as an expense that cannot be deducted for tax purposes.

3.2.5. Income taxes

Since 2012, the benefit in kind (BIK) used for tax purposes is calculated by applying a CO_2 percentage to 6/7 of the catalogue value of the vehicle, namely:

$$BIK = \text{catalogue value} * \%(CO2\ \text{coefficient}) * 6/7$$

The CO_2 base coefficient is 5.5% for a reference CO_2 emission that depends on the fuel type. If CO_2 emissions are higher than the reference CO_2 emissions, the base rate is increased by 0.1% per gram of CO_2, up to a maximum of 18%. If CO_2-emissions are lower than the reference CO_2-emissions, the basic percentage is reduced by 0,1% per gram CO_2, up to a minimum of 4%. If the company car is powered exclusively by an electric motor, the applied CO_2 percentage is equal to the minimum, namely 4%.

As can be seen in Table 10, the reference value for CO_2 emissions has decreased through time - this implies that the BIK for cars with high levels of CO_2 emissions has increased through time.

Table 10 Reference CO_2-emissions for the calculation of the BIK
g/km

Year	CNG	diesel	diesel hybrid	diesel PHEV	gasoline	gasoline hybrid	gasoline PHEV	LPG
2012	115	95	95	95	115	115	115	115
2013	115	95	95	95	115	115	115	115
2014	116	95	95	95	116	116	116	116
2015	112	93	93	93	112	112	112	112
2016	110	91	91	91	110	110	110	110
2017	107	89	89	89	107	107	107	107
2018	105	87	87	87	105	105	105	105
2019	105	86	86	86	105	105	105	105

The determined catalogue value is reduced, depending on the age of the vehicle, by 6% per year to a maximum of 30% - this is a complication that we are abstracting from here.

There is also a minimum amount for the BIK, which has been increased from 1,200 euros to 1,360 euros between 2012 and 2019 – see Table 11.

Table 11 Minimum value for the BIK
In euro

Year	Minimum BIK
2012	1200
2013	1200
2014	1230
2015	1250
2016	1250
2017	1250
2018	1280
2019	1310

3.2.6. Social security contributions

The employee is completely exempted from social security contributions on the use of a company car.

The employers' solidarity contribution is calculated as a monthly lump sum per vehicle that is made available to employees. This monthly contribution, which may not be less than EUR 20.83, depends on the level of CO_2 emissions and the type of fuel and is fixed on a flat-rate basis as follows:

- for petrol driven vehicles: [(Y x 9) - 768]: 12 = contribution (in EUR)
- for diesel powered vehicles: [(Y x 9) - 600]: 12 = contribution (in EUR)
- for LPG, CNG or methane-fuelled vehicles: [(Y x 9) - 990]: 12 = contribution (in EUR)
- for electrically propelled vehicles: EUR 20,83

where Y is the CO_2 emission content in grams per kilometre.

3.2.7. VAT deduction

The deductible share of VAT is proportional to the professional use of the company car, unless that professional use is more than 50%, in which case the deductible share is 0.65.

3.3. Assumptions regarding future policy developments

3.3.1. Impact of the European Policy Framework

On June 29, 2022, the Council agreed to increase the 2030 CO_2 emission reduction targets to 55% for cars and 50% for vans (Council of the EU, Press Release, June 29, 2022). Member States also agreed to a CO_2 emission reduction target for 2035 of 100% for new cars and vans.

As this proposal had previously been approved by the European Parliament, we assume in our analysis that this is decided policy.

In the context of CASMO, this means that we assume that no new combustion engine cars will be sold in Belgium from 2035 onwards.[8]

3.3.2. Low Emission Zone and fuel bans in Brussels

There is a Low Emission Zone within the whole territory of the Brussels Capital Region, with gradually more stringent restrictions. From 2030 on, no diesel powered cars will be allowed inside the LEZ. This ban generalizes to all gasoline powered cars in 2035.

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[8] Strictly speaking, the regulation only relates to a CO2 emissions reduction target, but in the absence of proven technological options for zero-emission combustion engines, we equate this to a ban on the sale of new combustion engine cars.

In CASMO, we have represented this as follows:

- At the end of the year before a tightening of the restriction, we set the survival probability equal to zero for all cars that are affected by a restriction (forcing the stock for this car to zero) and that are registered in Brussels.
- In the when the restriction enters into force, we set the acquisition cost equal to infinity for all cars affected by the restriction.

A big source of uncertainty with the LEZ lies in the wide range of possible behavioural responses by car owners who do not live in Brussels: switch to public transport or a rental car when they come to Brussels, buy a compliant car, etc. The actual response will depend on a range of factors, including the frequency and nature of the visits, the availability of alternative modes, the income of the car owner, how far away he lives from Brussels, etc. There are currently no data available that would allow to estimate a behavioural model.

We have made the conservative assumption that, besides inhabitants of the region, lease companies will comply with the LEZ.

Table 12 Low Emission Zone in Brussels

Year	Diesel (including hybrid models)	Gasoline (including hybrid models)
2022	Euro5 (and older)	Euro2 (and older)
2025	Euro6 (and older)	Euro3 (and older)
2028	Euro6d (and older)	Euro4 (and older)
2030	Not allowed	Euro6d (and older)
2035	Not allowed	Not allowed

3.3.3. Impact new WLTP test

All new cars registered from 1 September 2018 must undergo a new and more stringent type approval test for their emissions and fuel consumption (Commission Regulation (EU) 2018/1832 of 5 November 2018). The new WLTP test replaces the existing NEDC test. For already registered cars (tested with the NEDC test), the CO_2 value known at the time of vehicle registration remains valid.

Until December 31, 2021, carmakers must calculate a theoretical NEDC value, the so-called NEDC 2.0, for all their WLTP cars. All cars tested according to the new WLTP test will therefore always carry two CO_2 values until the end of 2021: NEDC 2.0 and the WLTP value. Vehicles tested according to the old NEDC test will retain their old CO_2 values.

In Belgium, CO_2 emissions per km affect the following taxes:

- Flanders: registration tax and annual road tax
- Wallonia: Ecomalus (from 146 g/km CO_2)
- Federal level:
  - benefit in kind on company cars used privately by employees and the self-employed;
  - tax deductibility of car expenses for the self-employed and companies;
  - solidarity contribution to social security for employers.

3.3.4. Registration tax and annual road tax

The Walloon government has reached a polical agreement on the reform of the registration and the annual road tax.[9] At this stage, this cannot be considered as decided policy.

3.3.5. Changes to the corporate income tax

The deductibility of fuel expenses remains as it is.

The deductibility of car expenses will be determined as of assessment year 2021 according to the following formula: 120% - (0.5% * coefficient * CO_2 emissions).

The coefficient is '1' for vehicles with only a diesel engine; '0.95' for other vehicles; and is increased to '0.9' for vehicles equipped with a natural gas engine and a taxable power of less than 12 fiscal horsepower. The percentage of deductibility thus obtained amounts to a minimum of 50% and a maximum of 100%. In deviation from this, the deductibility of vehicles with CO_2 emissions of 200 grams per kilometre or more is 40%.

For so-called "false hybrids" (rechargeable hybrid vehicles equipped with an electric battery having an energy capacity of less than 0.5 kWh per 100 kilograms of car weight or emitting more than 50 grams of CO_2 per kilometre), the CO_2 emissions taken into account for the above formula are those of the corresponding vehicle that is solely equipped with an engine that uses the same fuel. If there is no corresponding vehicle with an engine that only uses the same fuel, the CO_2 emission value will be multiplied by 2.5.

The changes introduced by the "Law on fiscal and social greening of mobility" of 25 November 2021 will enter into force in 2026 the deductibility of car expenses will be reduced to zero, except for electric cars (see Table 13).

Table 13 **Deductibility of electric car costs in corporate taxation**
%

Year	Deductibility
2026	100.0
2027	95.0
2028	90.0
2029	82.5
2030	75.0
As from 2030	67.5

3.4. Assumptions with respect to future developments

3.4.1. Prices

Since 2010, the prices of electric and hybrid cars have fallen very rapidly, and there is a broad consensus that the cost of batteries will fall even further in the next decade. In general, the so-called "grey literature" here is usually more optimistic than the estimates published in peer-reviewed scientific journals.

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[9] See https://www.wallonie.be/fr/actualites/vers-une-reforme-de-la-fiscalite-automobile.

For the latest version of CASMO, we used the price assumptions from Grube et al. (2021). Grube et al. use an extremely detailed bottom-up analysis, estimating for each individual component a learning curve that summarises how costs fall as a function of cumulative output over time:

$$C_Q = C_0 \left(\frac{Q}{Q_0}\right)^b$$

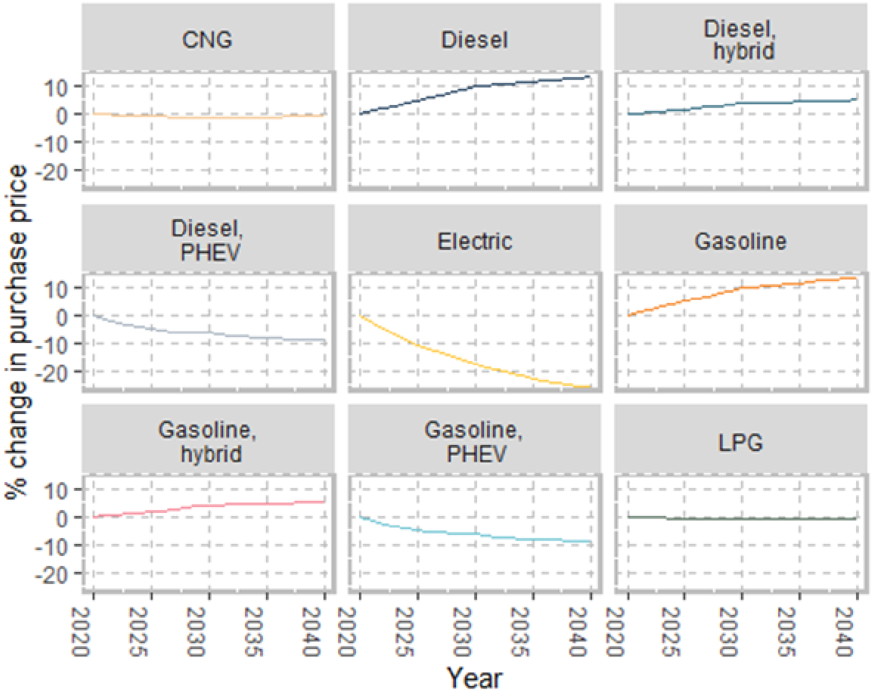
where C_Q is the production cost when cumulated production equals Q, and C_0 and Q_0 are the production cost and cumulated production in the year where obsrevations started. For each component of the cars, a specific parameter b is used.

In this formulation, the projections of future costs depend on the projections of future values of Q. Therefore, Grube et al. elaborate several scenarios corresponding to different assumptions on the future growth of electric and hybrid vehicle market shares.

For the needs of our study, we used the *BEV* scenario, where Grube et al. assume that electric cars reach a 65% market share worldwide in 2050.

Graph 11 summarises the evolution of the average purchase price of new cars under this assumption.

Graph 11 **Assumed future evolution of purchase prices: % change compared to 2019**



3.4.2. Fuel prices and consumption

Graph 12 summarises the assumptions we have used regarding the future evolution of fuel consumption for each COPERT class. The relative decrease compared to 2019 never exceeds 10%.

Graph 12 Fuel consumption new cars: percentage difference with 2019

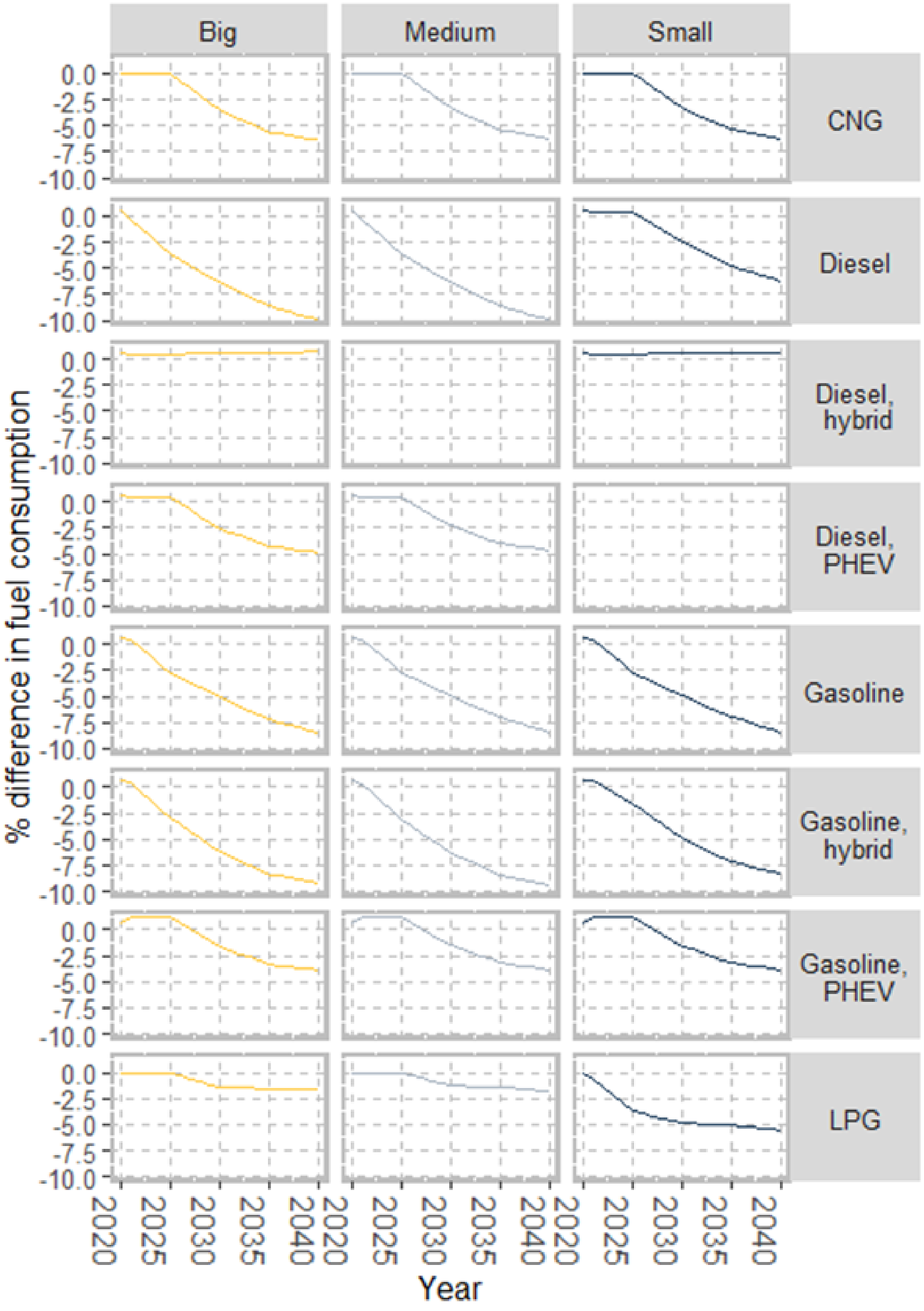


Table 14 summarizes the assumptions regarding the future evolution of the prices (before taxes) of fossil fuels.

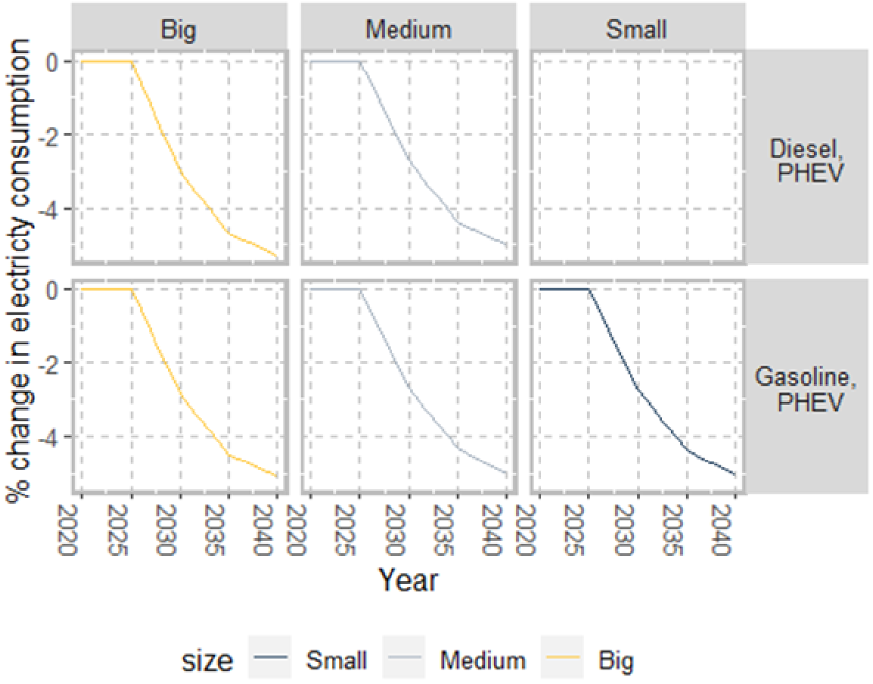
Table 14 Assumptions regarding the fuel prices (before VAT and excises, prices of 2019)

		2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
gasoline	Euro per litre	0.63	0.64	0.64	0.65	0.65	0.66	0.66	0.67	0.67	0.67	0.68
diesel	Euro per litre	0.66	0.67	0.67	0.68	0.68	0.69	0.69	0.70	0.70	0.70	0.71
LPG	Euro per litre	0.42	0.43	0.43	0.43	0.44	0.44	0.44	0.45	0.45	0.45	0.45
CNG	Euro per kg	0.85	0.85	0.86	0.87	0.88	0.89	0.89	0.90	0.91	0.92	0.93

3.4.3. Electricity: prices and consumption

For electric cars, we assume that the electricity consumption per km of new cars remains constant. Graph 13 summarises the assumptions for plug-in hybrid cars. Thus, we assume that electricity consumption of plug-in hybrids remains constant until 2025, and then declines slightly, with a maximum of 5% compared to 2019.

Graph 13 Electricity consumption per km of new cars: % difference with 2019



We assume a constant price of 19.51 euro cent per kWh.

3.5. Model results with CASMO

3.5.1. The life cycle of passenger cars as a multi state process

Between the initial purchase of a car and its final scrapping, a car may change owner one or more times. Since some taxes depend on the region (like the annual road tax) or on the type of owner (all taxes specific to company cars), it seems useful to model not only the final scrapping of a car, but also all intermediate changes.

For this purpose, we make use of techniques developed for modelling so-called multi state processes – these are models that represent the transitions through (continuous) time between a finite number of discrete states – a typical application are the various stages that a patient may pass through between diagnosis and death (or definitive cure). The analogy with the successive "types of owner of a car" is obvious.

Here we have used Markov models in continuous time. These are defined by so-called transition intensities between different states r, s:

$$q_{rs}\big(t, z(t)\big) = lim_{\Delta t \to 0} \frac{P(S(t + \Delta t) = s|S(t) = r)}{\Delta t},$$

where $z(t)$ represents all variables that can affect the transition intnesity.

Under the Markov hypothesis, it is assumed that $q_{rs}\big(t, z(t)\big)$ only depends on the current state.

These transition intensities can be used to calculate the probability that someone who is now in state r will be in states s in t times units from now, $p_{rs}(t)$.

To estimate the multi state process of the Belgian car fleet from DIV data, we used the msm package written in the R language (Jackson, 2011).

We defined four possible stages (the numbering is arbitrary and does not imply that these stages are sequential):

- Stage 1: a car is owned by a leasing firm.
- Stage 2: A car is owned by a private person.
- Stage 3: A car is owned by by legal entity that is not a leasing firm
- Stage 4: A car is permanently scrapped.

Note that the stage “definitively scrapped” does not exist as a separate category within the DIV database. For each year of the period, the DIV only reports whether a car that was registered with the DIV during the year was deregistered from the DIV database by the end of the year. Such deregistrations are not necessarily definitive since the car may have been sold on the second-hand market and a certain period of time may elapse between the deregistrations by the seller and the registration by the buyer.

Note that a more detailed specification of these stages (e.g. to take into account the Region of registration) resulted in non-convergence of the estimation algorithms used. Consequently, we assumed that a car does not change its Region over its lifetime.

We used two independent variables to estimate $q_{rs}\big(t, z(t)\big)$: the age of the car on the one hand, and the cartype on the other. Because the estimation algorithms did not converge when we used the original cartypes, we aggregated them into the following categories: petrol, diesel, electric, all hybrids (including PHEVs) and CNG and LPG cars as a residual category.

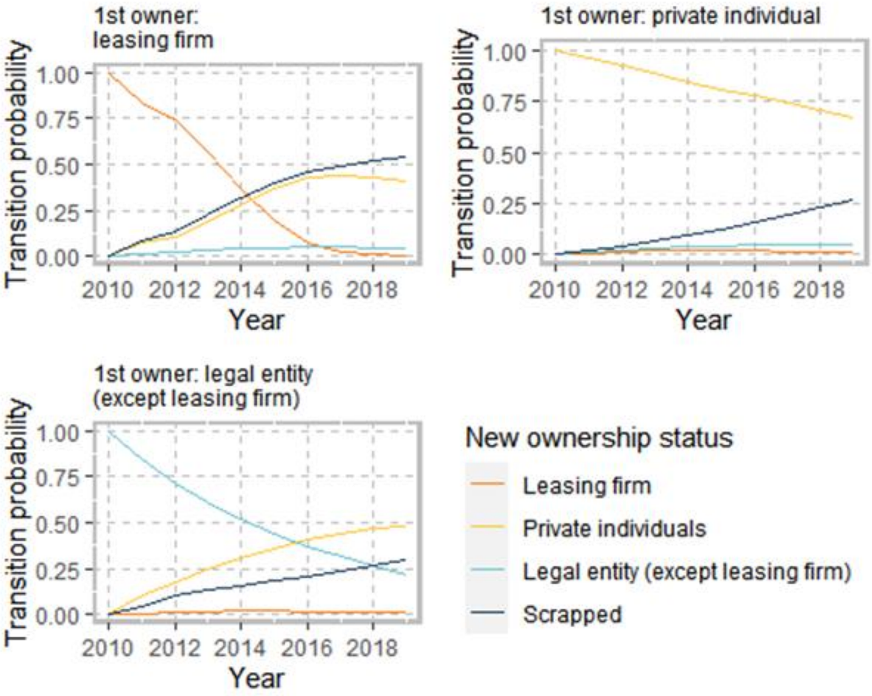
As such, the model estimates are not very informative. Instead, Graph 14 gives the values of $p_{rs}(t)$ for all diesel cars that have been first registered in 2010, for $t = 2010, \dots, 2020$.

On the top left we see the transition probabilities for cars initially registered by leasing companies in 2010. We see a very rapid decrease in the number of leased cars that remain in the hands of a leasing company – after three years already half of them have changed type of owner, and after six years almost none of them remain the property of a leasing company. Only a very small fraction of them are resold to other legal entities: they are either sold to private individuals or permanently scrapped (probably exported for the second-hand market).

On the top right, we see the transition probabilities for cars initially purchased by private individuals in 2010. Almost none of these are sold on to legal entities. After ten years, almost three quarters are still in the hands of private individuals.

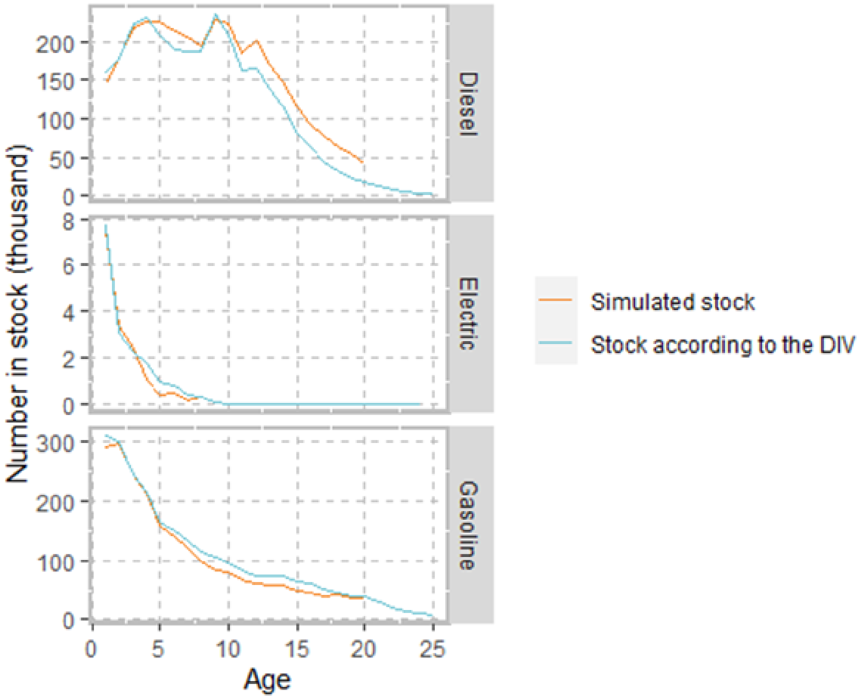
Finally, in the bottom left-hand corner, we see the transition probabilities for cars initially purchased by legal entities (except leasing companies) in 2010. The pattern is similar to what we observed for leased cars, but much slower. After ten years, more than 10% are still in the hands of legal entities, and 50% in the hands of private individuals.

Graph 14 Successive stages for a diesel car



In Graph 15, we compare the age structure of the observed park in 2019 with that of a simulated park. We obtained the simulated park by applying the estimated Markov process to the sales figures between 2000 and 2019 obtained from IHS. This shows that the simulated and real values are very close. However, since the available sales figures only go back to 2000, we are not able to model the “tail” of very old cars.

Graph 15 Age structure of a simulated car stock versus the observed car stock



3.5.2. Model results for the discrete-choice model

The discrete-choice model was estimated using the BLPestimatoR package, written in R (Brunner, Weiser and Romahn 2019).

In this paper, we mainly discuss the results of our estimations. A detailed technical description of this approach can be found in Appendix B.

As discussed above, several fiscal parameters are defined by the regions, except for cars owned by leasing companies, where an interregional agreement is needed to modify the existing system. For each year, we therefore define seven markets: one national model for leased cars, and three regional models for cars owned by private persons or other legal entities.

In Annex C, we have also shown that, for company cars, we cannot simply take the purchase price as indicator of its capital cost. We have therefore estimated a separate choice model for private owners and legal entities (covering both leasing companies and other legal entities).

Here we first discuss the common elements of both models.

First, as described above, the BLP requires the definition of an "outside good" corresponding to the option "not to buy a car".

The standard approach is to estimate the market potential, and define the choice probabilities against that market potential. For example, if the number of cars that could potentially be bought in a hypothetical market during a given year is 1 million, and 50,000 units of model X are sold, then the choice probability for model X equals 0.05.

However, there is no data available that allows us to directly test this estimate of market potential. Huang and Rojas (2011, 2013) have shown that this can lead to a bias in the estimation of the model parameters. The question then arises as to how robust the model is to the specific value chosen for market potential.

In CASMO, we proceeded as follows: (a) we measured the maximum number of cars sold per year in the period 2013-2019 for each regional owner type combination. (b) We defined the market potential as a multiple q of that maximum. We then estimated the model for $q = 1.6, \ldots, 5.2$ (with jumps of 0.6).

By comparing the model results for different values of q, we were able to confirm the robustness of the estimated parameter values.

A second step is to calculate the average price in each market, and divide the price of each car model by the average price. By working with the relative price, we avoid a common problem in numerical methods, namely that the algorithm does not converge because the variables are not correctly scaled.

As a third step, we looked at which demographic variables can be used to estimate the random coefficients in the discrete choice model. In a first version of the model, where the markets were not yet split by region and owner type, we used the results of the BELDAM survey (Cornelis et al. 2012). However, these data are not usable for the differentiated model.

The more recent MONITOR survey is usable in principle, but for some markets the sample is very small. The results of the BLP algorithm are only robust if the sample used for estimating the random coefficients is sufficiently large (see Brunner et al. 2017).

We have therefore restricted ourselves to unobserved heterogeneity for estimating the random coefficients, taking 5000 random draws from the standard normal distribution.

The fourth step is then to formulate the model and create a blp_data object with the BLP_data(). Such a blp_data object combines all the data and parameters needed to run the BLP algorithm.

In addition to the built-in consistency and completeness checks of BLP_data(), we check ex ante whether our model specification could lead to singular matrices in the calculations. Since the main reason why singularity might occur is multicollinearity between categorical variables, we developed an algorithm where one categorical variable is eliminated from the model as long as the ex ante checks detect singular matrices.

The fifth step consists of estimating the model. This starts with a random draw from the normal distribution with $\mu = 0$ and $\sigma = 0.1$ for the initial values of the random coefficients (note that the model usually does not converge for larger values of σ, probably because this leads to scaling problems).

The model is estimated with the estimateBLP() function. We use the "L-BFGS-B" method for the numerical procedure - Conlon and Gortmake (2020) have shown it to be preferable to alternatives such as the Nelder-Mead. The model is initially estimated with homoscedastic error terms.

When using numerical methods, there is no guarantee that the algorithm will converge, or that it will converge to a global optimum. Therefore, to verify the robustness of the results, the above procedure is repeated several times[10].

Finally, we have taken the results of the model with the lowest value for the GMM objective function as starting values for reestimating the model with heteroscedastic error terms.

Table 15 gives the estimated linear coefficients for the BLP model for private car owners.

PriceRatioVar is the ratio of the individual model's price (including the registration tax) to the average market price (including the registration tax). The estimated coefficient has the expected sign and is highly significant.

MediumWght, *HighWght* and *VeryHighWght* are categorical variables corresponding to cars whose weight is between the 1st quartile and the median, between the median and the third quartile, and between the third quartile and the maximum, respectively. These coefficients are not significant. The interaction variables with *PriceRatioVar* are also found not to be significant.

log10(I(TraffTax + 1)) is the logarithm with base ten of the annual road tax[11]. The estimated coefficient has the expected sign and is significant at the 0.1 level.

FuelCostCarKmInd is the cost of fuel consumption and/or electricity consumption, based on the EEA values for individual models. The estimated coefficient has the expected sign and is highly significant.

For the car types, we defined five categorical variables: SUV, LDV, Convertible, SportsCar and FamilyCar. The reference category consists of minivans that are also used as passenger cars. All coefficients are found to be highly significant. This is also the case with the interaction variables with *PriceRatioVar*.

The categorical variables for Japanese and French cars are significant, but those for German and Korean cars are not. The fact that there is no specific effect in favor of German cars was somewhat surprising.

There is a very significant brand effect in favor of Tesla.

We also estimated interaction effects for engine types, using LPG cars as reference category. These effects are significant only for gasoline, diesel, gasoline hybrid, and gasoline PHEV cars. With the exception of electric and diesel PHEVs, all cars appear more attractive than LPG cars ceteris paribus. This effect is much stronger for gasoline cars than for diesel cars.

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[10] A dozen draws is usually sufficient with the data and the model we use

[11] The term '+1' was added to obtain a real value when the road tax is zero

Finally, we estimated an interaction variable between the price indicator on the one hand and a set of categorical variables on the other. In addition to the car body types and weight classes, we also consider an indicator variable for the ratio of the car's maximum power to its weight.[12].

The interaction variables with the body types all turn out to be highly significant.

Table 15 Linear coefficients for the BLP model for private persons

	Estimate	Std. Error	t value	Pr(>|t|)
PriceRatioVar	-8.21	1.27	-6.48	0.00
MediumWght	-0.85	6.09	-0.14	0.89
HighWght	-1.40	14.38	-0.10	0.92
VeryHighWght	-3.34	10.53	-0.32	0.75
log10(I(TraffTax + 1))	-0.54	0.29	-1.90	0.06
FuelCostCarKmInd	-34.15	6.56	-5.21	0.00
SUV	-9.07	0.72	-12.67	0.00
LDV	-7.81	0.92	-8.49	0.00
SportsCar	-10.83	0.92	-11.83	0.00
FamilyCar	-9.61	0.65	-14.74	0.00
Convertible	-10.87	0.77	-14.19	0.00
GermanCar	0.12	0.10	1.23	0.22
JapCar	-0.24	0.11	-2.07	0.04
KorCar	-0.12	0.09	-1.32	0.19
FrenchCar	0.37	0.07	5.40	0.00
Tesla	2.51	0.68	3.68	0.00
gas	3.76	0.57	6.57	0.00
dies	2.13	0.58	3.71	0.00
gashybr_cs	3.21	0.59	5.41	0.00
gashybr_phev	2.06	0.55	3.78	0.00
dieshybr_phev	-0.68	1.32	-0.51	0.61
CNG	0.62	0.45	1.39	0.17
electric	-0.26	0.44	-0.59	0.56
dieshybr_cs	0.19	1.70	0.11	0.91
PriceRatioVar:SUV	10.60	1.06	9.99	0.00
PriceRatioVar:LDV	8.32	1.05	7.95	0.00
PriceRatioVar:SportsCar	11.02	1.09	10.13	0.00
PriceRatioVar:FamilyCar	10.29	1.01	10.19	0.00
PriceRatioVar:Convertible	10.82	1.03	10.51	0.00
PriceRatioVar:MediumKwPerKg	-0.41	3.01	-0.14	0.89
PriceRatioVar:HighKwPerKg	-2.60	3.32	-0.78	0.43
PriceRatioVar:VeryHighKwPerKg	-4.46	2.12	-2.11	0.03
PriceRatioVar:MediumWght	0.68	0.97	0.70	0.48
PriceRatioVar:HighWght	0.70	1.24	0.56	0.57
PriceRatioVar:VeryHighWght	1.42	0.95	1.48	0.14

Table 16 provides the estimated random coefficients for the BLP model for individuals. As mentioned above, we restrict ourselves here to unobserved heterogeneity. Only the coefficient for the categorical variable *VeryHighKwPerKg* turns out to be significant.

Table 16 Random coefficients for the BLP model for private persons

	Estimate	Std. Error	t value	Pr(>|t|)
unobs_sd*FuelCostCarKmInd	-0.19	176.57	0.00	1.00
unobs_sd*MediumKwPerKg	-0.06	44.37	0.00	1.00
unobs_sd*HighKwPerKg	-1.52	2.87	-0.53	0.60
unobs_sd*VeryHighKwPerKg	2.74	1.34	2.05	0.04
unobs_sd*MediumWght	-0.39	15.83	-0.02	0.98
unobs_sd*HighWght	0.90	17.30	0.05	0.96
unobs_sd*VeryHighWght	-1.83	6.78	-0.27	0.79
unobs_sd*PriceRatioVar	-0.68	0.68	-1.01	0.31

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[12] Where we use the quartiles of the distribution to delineate the categories

For the interpretation of these random coefficients, we refer to Appendix **: In the BLP approach, the utility that consumer n derives from product j in year t consists, among other things, of a term that varies across consumers, $\tilde{V}(p_{jt}, x_{jt}, s_n, \tilde{\beta}_n)$ where p_{jt} is the price of product j in year t, x_{jt} is the vector of observed* non-price characteristics, s_n is a vector of consumer demographic characteristics (if available), and $\tilde{\beta}_n$ is a vector of coefficients that vary across consumers.

$\tilde{\beta}_n$ is a function of, on the one hand, a vector of (observable) demographic variables D_n and, on the other hand, a vector v_n representing the unobserved heterogeneity: $\tilde{\beta}_n = \Pi\ D_n + \Sigma\ v_n$. Π and Σ are the matrices of coefficients to be estimated.

Since (as discussed above) we do not have a large enough dataset of demographic data by market, we have only estimated Σ for a vector v_n that follows a standard normal distribution.

For example, if a random draw from the standard normal distribution gives $unobs_{sd} = 0.7$ and the car model X has $VeryHighKwPerKg = 1$, then $1{,}918 = 2.74 * 0.7$ should be added to the utility resulting from the purchase of model X.

The estimated coefficients are those which, for a large number of random draws from the standard normal distribution, maximize the probability that the estimated market shares are equal to the real observed market shares - hence we speak of Simulated Maximum Likelihood.

Table 17 provides the estimated linear coefficients for the BLP model for company cars.

The variables have the same meaning as for individuals, except:

- For the price variable, we use FS_{SC} as defined in Appendix B. This term also takes into account tax parameters specific to company cars: corporate tax deductibility, VAT (partial) deductibility, non-deductible expenses of the benefit in kind and employer solidarity contribution.
- For the cost of fuel consumption, we also take into account the (partial) deductibility of VAT.
- We have an additional term corresponding to SS_{CC}, the indicator for the salary cost saved.

As with privately owned cars, the estimated coefficient for *PriceRatioVar* has the expected sign and is highly significant.

MediumWght, *HighWght* and *VeryHighWght* again turn out not to be significant.

log10(I(TraffTax + 1)) and *FuelCostCarKmInd* have the expected sign but are not significant.

The results for the body types again turn out to be significant.

The nationality and brand effects are similar to those we obtain for individuals. The significance of the coefficient for German cars remains relatively low.

The significance of the categorical variables defined for engine types turns out to be much lower than for individuals, except for gasoline hybrids and gasoline PHEVs. This means that for company cars, the advantages and disadvantages of the different engine types are better capture by the measured variables than for individuals.

Again, only the interaction variables with the body types prove highly significant.

Table 17 Lineair coefficients of the BLP model for company cars

	Estimate	Std. Error	t value	Pr(>|t|)
PriceRatioVar	-8.91	0.73	-12.19	0.00
MediumWght	-19.00	20.23	-0.94	0.35
HighWght	-43.16	54.63	-0.79	0.43
VeryHighWght	-0.69	25.34	-0.03	0.98
log10(I(TraffTax + 1))	-0.36	0.23	-1.55	0.12
I(SavedCapCostEmployee/1000)	0.00	0.01	0.01	0.99
FuelCostCarKmInd	-15.08	10.30	-1.46	0.14
SUV	-9.96	0.63	-15.79	0.00
LDV	-10.66	0.80	-13.30	0.00
SportsCar	-10.69	0.69	-15.55	0.00
FamilyCar	-10.46	0.65	-16.03	0.00
Convertible	-11.20	0.68	-16.49	0.00
GermanCar	0.45	0.08	5.47	0.00
JapCar	-0.45	0.16	-2.91	0.00
KorCar	-0.56	0.25	-2.23	0.03
FrenchCar	1.18	0.24	4.91	0.00
Tesla	6.84	0.82	8.37	0.00
gas	2.91	0.75	3.88	0.00
dies	2.53	0.63	4.00	0.00
gashybr_cs	4.04	0.77	5.24	0.00
gashybr_phev	3.12	0.68	4.57	0.00
dieshybr_phev	1.79	0.77	2.32	0.02
CNG	1.24	0.60	2.07	0.04
electric	1.48	0.72	2.04	0.04
dieshybr_cs	0.87	0.59	1.48	0.14
PriceRatioVar:SUV	9.53	0.55	17.19	0.00
PriceRatioVar:LDV	9.22	0.61	15.12	0.00
PriceRatioVar:SportsCar	9.48	0.59	16.04	0.00
PriceRatioVar:FamilyCar	9.35	0.58	16.01	0.00
PriceRatioVar:Convertible	9.61	0.62	15.51	0.00
FuelCostCarKmInd:MediumKwPerKg	-1.81	9.73	-0.19	0.85
FuelCostCarKmInd:HighKwPerKg	-6.27	5.99	-1.05	0.30
FuelCostCarKmInd:VeryHighKwPerKg	-7.70	7.01	-1.10	0.27
PriceRatioVar:MediumKwPerKg	0.10	0.44	0.24	0.81
PriceRatioVar:HighKwPerKg	-0.40	0.55	-0.72	0.47
PriceRatioVar:VeryHighKwPerKg	-0.65	0.62	-1.04	0.30
PriceRatioVar:MediumWght	0.29	0.36	0.80	0.42
PriceRatioVar:HighWght	0.17	0.70	0.25	0.80
PriceRatioVar:VeryHighWght	0.50	0.25	1.96	0.05
PriceRatioVar:GermanCar	-0.21	0.06	-3.63	0.00
PriceRatioVar:JapCar	-0.56	0.17	-3.29	0.00
PriceRatioVar:KorCar	-0.59	0.31	-1.92	0.06
PriceRatioVar:FrenchCar	-0.87	0.33	-2.65	0.01
PriceRatioVar:Tesla	-2.56	0.57	-4.46	0.00

Table 18 gives the estimated random coefficients of the BLP model. None are significant, except the coefficient for the categorical variable *VeryHighWght*.

Table 18 Random coefficients of the BLP model for company cars

	Estimate	Std. Error	t value	Pr(>|t|)
unobs_sd*FuelCostCarKmInd	-0.24	147.09	0.00	1.00
unobs_sd*MediumKwPerKg	0.08	15.50	0.01	1.00
unobs_sd*HighKwPerKg	0.02	27.52	0.00	1.00
unobs_sd*VeryHighKwPerKg	-0.01	47.44	0.00	1.00
unobs_sd*MediumWght	14.10	13.35	1.06	0.29
unobs_sd*HighWght	-27.62	32.87	-0.84	0.40
unobs_sd*VeryHighWght	0.78	36.46	0.02	0.98
unobs_sd*PriceRatioVar	0.18	0.69	0.26	0.80

3.6. Recalibration based on market shares 2020-21

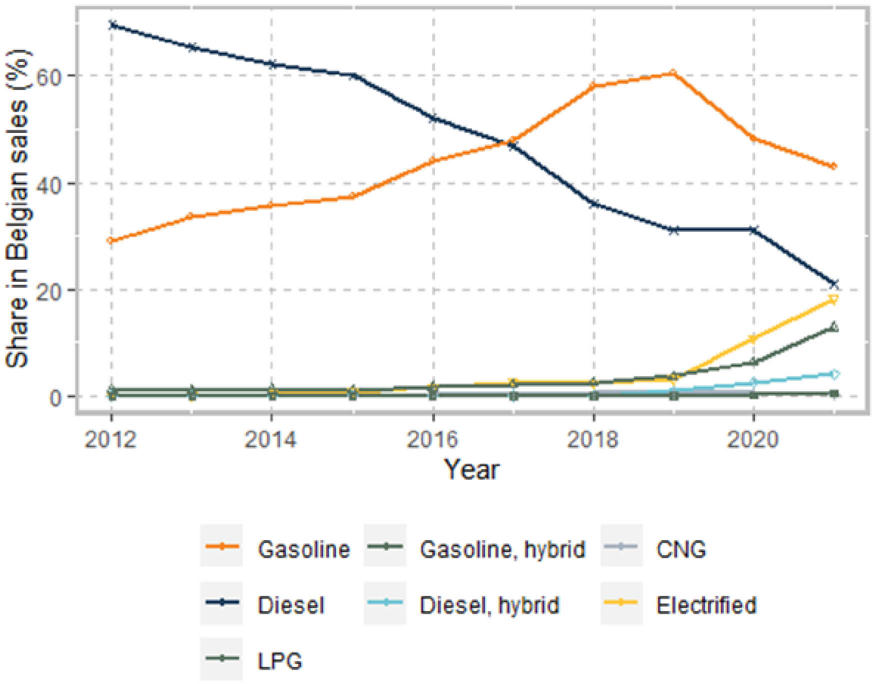
Graph 16 summarises the national market shares by engine type for the entire period 2012-2021, where we have grouped all electric and hybrid cars under the heading “electrified”. In Graph 17 we zoom in on the electric and hybrid cars.

Two things stand out here.

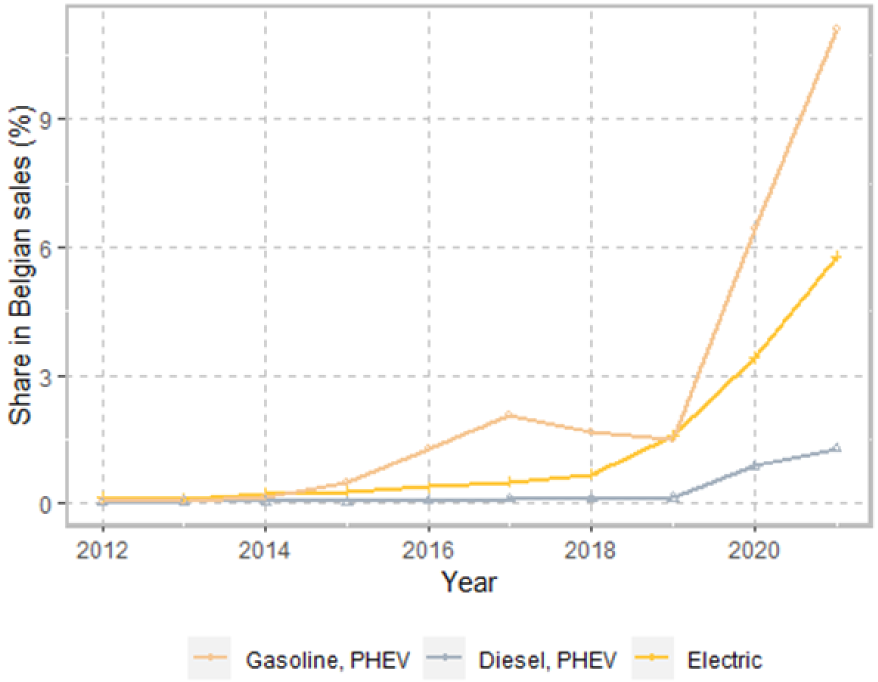
Firstly, up to and including 2019, the market shares of petrol and diesel cars are almost mirror images of each other, with a very clear impact of the “dieselgate” scandal.

Secondly, despite a steady increase in the market shares of electric and hybrid cars, their market shares remained very small until 2019, before suddenly rising significantly in 2020. The most spectacular increases are due to petrol hybrids and petrol PHEVs, but the market share of electric cars has also exceeded 5%. Even the market share of diesel hybrid cars is approaching 5% for the first time.

Graph 16 Market shares from 2012 to 2021 (own calculations based on DIV data)



Graph 17 Market shares from 2012 to 2021 for electric and PHEV cars (own calculations based on DIV data)



This sudden increase in the market share of electric and hybrid cars is mainly supply driven: it follows from the need for car manufacturers and importers to comply with EU legislation[13] on average CO_2 emissions from new cars. As this legislation will become even stricter in the future, we can assume that the effect will be permanent.

However, we do not have individual sales data for the period 2020-21. We therefore continue to use the choice model estimated from 2013-19 sales transactions, but recalibrate the model so that the forecasted market shares per engine type match the observed market shares. We do this by acting on the categorical variables that correspond to the engine types: indeed, the estimated coefficients for these variables represent the advantages and disadvantages of each engine type that are not captured by measured quantities such as the cost variables, weight or maximum power. Instead of the coefficients, however, we adjust the categorical variables themselves.

The algorithm is inspired by the one used by Berry (1994, 1995) to calculate the δ_{jt}:

- For each year, we calculate the choice probability of each individual car according to the procedure described in Annex B.
- We aggregate these results to calculate the total predicted market share by engine type, and compare it with the observed market shares.
- We calculate a correction term for each engine type f, $\xi_f = \ln\left(\frac{S}{\hat{S}}\right)$ where S is the observed market share, and $\hat{S}$ is the predicted market share.

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[13] Regulation (EU) 2019/631 of the European Parliament and of the Council

- The correction factor is now rescaled as a function of β_f, the estimated coefficient for the corresponding categorical variable in the BLP model: ${\xi_f}' = \frac{\xi_f}{\beta_f}$.
- For each individual car in the dataset, the corresponding categorical variable for the engine type is adjusted according to $D = D + {\xi_f}'$.
- This procedure is repeated until when $\sum\left|S - \hat{S}\right| < \epsilon$ where $\epsilon = 10$ or until the maximum number of iterations is reached.

Note that setting ${\xi_f}' = \frac{\xi_f}{\beta_f}$ ensures that the adjustment of the categorical variable is in the right direction. For example, if $\xi_f < 0$ $\left(S < \hat{S}\right)$, then in the next iteration we want the predicted market share to decrease as well. If $\beta_f < 0$, then $\xi_f/\beta_f > 0$, causing D to increase in value. If, on the other hand, $\beta_f > 0$, then $\xi_f/\beta_f < 0$, causing D to decrease in value. In both cases, we get the intended correction.

3.7. Yearly update of the car stock

3.7.1. Organisation of the car stock in CASMO

We take all cars from the DIV's database that had not been scrapped by the end of 2019 and group the cars according to the following criteria:

- The COPERT class, which is determined by cartype and engine size. As mentioned above, electric vehicles are classified according to battery capacity.
- The last region where the car was registered (Brussels Capital Region, Flanders, Wallonia).
- The type of owner (private individuals, legal entities excluding leasing companies, leasing companies).

3.7.2. Estimation of market share per individual model

We recalculate the market shares for each year in the projection period.

An important technical limitation of BLPestimatoR is that the estimateBLP() only allows estimating market shares for cars and markets used in the model estimation - this is intrinsic to the BLP algorithm, as estimating the model also involves estimating alternative-specific constants $\{delta_{jt}$, parameters specific to the individual car model.

Thus, it is not possible to "create" new car models with given technical characteristics that are added to the list of car models for which the model is estimated. For the projections in future years, we therefore use the car models that we used in the estimations, but we let certain parameters (such as price or fuel consumption) evolve over time.

We have used the following procedure to deal with this:

- We take the observations from the base year 2019 that we used to estimate the model.

- We update all variables to the situation in the current year. First, this means that the purchase price for electric and hybrid cars is adjusted according to the so-called "BEV" scenario from Grube et al. (2021). In addition, fuel and electricity prices and the use of the cars are adjusted according to the scenarios described in section 3.4. Finally, we adjust all fiscal parameters (registration tax, annual road tax, corporate income tax) if they change during the projection period according to the considered scenario.
- Then, the market shares are recalculated by applying these assumed values to the base year 2019.

The following points should be noted:

- In 2020 and 2021 the categorical variables are re-estimated according to the procedure described in Section 3.6.
- From 2022 onwards we use the categorical variables as re-estimated in 2021.
- As we have estimated a separate discrete choice model for company cars, the market shares for company cars will also be recalculated separately.
- A market is defined by the combination year-region-owner type, and each market has its own "outside good".

From 2030 onwards, it will be forbidden to drive a diesel car in Brussels. We assume that individuals and companies domiciled in Brussels will no longer buy diesel cars after that date. It is less clear how people who do not live within the BCR will behave. It seems likely that people who now commute to Brussels by car will, if necessary, replace their diesel car with another car. However, for people who now only occasionally come to Brussels, other options are possible, such as keeping the diesel car and taking public transport or using a shared car when going to Brussels. However, we have not identified any data that would allow us to identify this group. In what follows, we will assume that leasing companies will also comply with this ban, even if they are not registered in Brussels.

In the discrete choice model, we represent a ban on new purchases by an infinite road tax.

The output of the choice model is, for each car model and each market, a probability defined with respect to the market potential. Use $p_{i,g,e,t}$ to represent the choice probabilities for car model i (with I the set of all models) in region g (with G the set of all regions), with owner type e (with E the set of all owner types) in year t. $Pot_{g,e}$ is the market potential and $S_{i,g,e,t}$ are the sales.

We now use this to estimate sales per model.

There are two ways to estimate sales by model.

- **RegSharesBLP** A first possibility is to multiply $p_{i,g,e,t}$ by the market potential: $S_{i,g,e,t}^{Est1} = p_{i,g,e,t} * Pot_{g,e}$. The total sales in year j are then: $S_t^{Est1} = \sum_{i\in I, g\in G, e\in E} p_{i,g,e,t} * Pot_{g,e}$
- **RegSharesBaseYr** A second possibility is to proceed as follows:
  - For each market, we calculate $\sum_{i\in I} \quad p_{i,g,e,t}$ - note that this sum is nothing but the ratio of the total estimated number of purchases in that market to the total market potential.

- We then recalculate, market by market, the choice probability for each individual model against this sum: $p'_{i,g,e,t} = \frac{p_{i,g,e,t}}{\sum_{i\in I} p_{i,g,e,t}}$. In other words, we now formulate the choice probabilities as shares in the effective sales *per market*, rather than in the total market potential.
- For total sales per market, however, we take the observed sales in the base year, 2019. Then we obtain: $S^{Est2}_{i,g,e,t} = p'_{i,g,e,t} * \sum_{i\in I} \; S_{i,g,e,2019}$.
- For total sales, we obtain $S^{Est2}_{t} = \sum_{i\in I,g\in G,e\in E} S^{Est2}_{i,g,e,t} = \sum_{i\in I,g\in G,e\in E} p'_{i,g,e,t} * \sum_{i\in I} \; S_{i,g,e,2019}$

RegSharesBLP results in direct estimates of sales and seems 100% consistent with the BLP methodology. On closer inspection, however, this is not the case. Because $p_{i,g,e,t}$ is defined against market potential, rather than against total sales, changes in prices can lead to a change in the total number of sales within a given market. For example, if all leased cars become cheaper, then total sales of leased cars will increase. This seems at first sight a desirable result, but we must keep in mind that the BLP algorithm assumes that the different markets are independent of each other, and in reality this is not strictly. For example, in the example we consider here, this means that the BLP algorithm does not take into account that an increase in sales of leased cars may lead to a decrease in sales of cars to individuals if households see a company car (in part) as a substitute for an owned car.

Full consistency with the BLP methodology is therefore not feasible.

By working with **RegSharesBaseYr** we avoid this problem: the shares of each market in total Belgian sales remain stable over time. A drawback of this approach is that changes in price parameters cannot lead to changes in total sales: for example, measures that make *all* cars more expensive will not lead to people buying fewer cars, only to a shift within the composition of sales.

However, as we will see below, in CASMO we do not use either S^{Est1}_{t} or S^{Est2}_{t} to update the existing fleet. The choice between **RegSharesBLP** and **RegSharesBaseYr** only determines the *composition* of the sales, not their total size.

3.7.3. Update of the car park at the level of the COPERT classes

In each projection year, we use the following formula to estimate the desired number of cars per person in Belgium:

$$Stock^{*}_{t} = 0.6110456 * e^{-8.3851 * e^{-0.00013 * BBP_t pop_t}} * pop_t$$

where $Stock^{*}_{t}$ is the desired number of cars, BBP_t is the gross domestic product in constant prices and pop_t is the population, in each case in year t. The coefficients are estimated based on historical relationships in Belgium (see Franckx 2019 for details).

Next, we take $Stock_{t-1}$, the car fleet of the previous year. $Stock_{t-1}$ gives the total number of cars per engine type, size class, region, owner type and year. In 2020, $Stock_{t-1}$ is directly based on the 2019 DIV database. The total number of cars in this stock is St_{t-1}.

We now apply the survival functions to $Stock_{t-1}$ to estimate the number of cars scrapped per vintage by COPERT class, region and owner type. The total number of cars scrapped is then $Scrap_t$. If a particular region prohibits certain types of engine (for example, a diesel ban or a Low Emission Zone), then the survival functions can be adapted to express that all cars that run on a given fuel or exceed a certain age are scrapped.

We then assume that $Sales_t$, the total number of sales at the national level, fills the difference between the desired and the surviving stock:

$$\text{Sales}_t = \text{Stock}_t^* - \left(\text{Stock}_{t-1} - \text{Scrap}_t\right)$$

In order to allocate this total to the individual COPERT classes, we use the results of the discrete choice model.

A complication here is that the discrete choice model does not take into account the region where the car is registered in the case of leased cars: the registration and the annual road tax for leased cars are indeed determined nationally. However, as the fleet is split up regionally, we assume that the regional distribution of new leased cars remains proportional to their regional distribution in $Stock_{t-1}$.

We calculate the total number of cars sold per COPERT class C, region c and owner type e as (where, as explained in section 3.7.2, $p_{i,g,e,t}^{Est}$ is the estimated probability of choice of model i relative to the total market potential and $\frac{p_{i,g,e,t}}{\sum_{i\in I} p_{i,g,e,t}}$ is the choice probability of model i relative to all other models):

$$\text{Sales}_{C,g,e,t}^{Est} = \left(\sum_{i\in C, g\in G, e\in E} \frac{p_{i,g,e,t}}{\sum_{i\in I} p_{i,g,e,t}}\right) \text{Sales}_t$$

Note that $\text{Sales}_t \neq S_t^{Est1} \neq S_t^{Est2}$. The reason why we work here with S_t rather than with a direct application of the output of the BLP model is that this is the only way to represent measures such as a diesel ban or a Low Emission Zone. The diesel ban in the Brussels Capital Region, for example, does not just apply to new cars, but also to the existing car stock. If we assume that the total demand for cars in Belgium does not change, this means that an increase in sales of non-prohibited cars will have to compensate for the early scrapping of diesel cars.

In the approach we use here, we assume that this compensation is complete: each scrapped vehicle is immediately replaced by a new vehicle at the end of the year that the tightening of the LEZ takes effect.

4. Discussion of the simulation results

We discuss the projections based on the hypothesis that the increase in the shares of electric, hybrid and plug-in hybrid cars in 2020-21 represents a fundamental trend change that will continue thereafter - in other words, these are projections with recalibrated categorical variables for the engine types (see section 3.6).

Alternative hypotheses are discussed in the appendices.

Given the very low market shares of LPG, CNG, diesel hybrid and diesel plug-in hybrids, these are - to improve the readability of the graphs - not presented graphically.

4.1. Results with recalibrated categorical variables

Graph 18 shows the evolution of sales of new company cars, both for the reference scenario without tax reform and for the scenario with tax reform. The panel on the right shows the difference between the two.

In the reference scenario, we see a significant increase in sales of gasoline PHEVs and of electric cars. Initially, sales of gasoline PHEVs grow faster than those of electric cars. From 2028 onwards, sales of electric cars grow faster and after 2029 their market share even exceeds that of gasoline PHEVs.

Sales of diesel and gasoline cars decline rapidly. The peaks in sales correspond to tightened entry conditions in the Brussels Low Emission Zone (LEZ): since these tightenings lead to cars being phased out prematurely, additional purchases are needed to keep the total fleet at the desired level.

In reality, the LEZ will lead to more gradual changes. This is because people can anticipate the next phase of the access restriction - for example, it is unlikely that they will buy new diesel cars in the year preceding the diesel ban. However, this anticipation effect will be less pronounced in the market for company cars, since leased cars in particular are resold relatively quickly. The peaks for company cars will thus be smoothed out over two or three years at most.

Stricter access restrictions will also lead to a new dynamic on the second hand market in Belgium: some cars that will no longer have access to the LEZ will be resold to owners in Flanders and Wallonia. However, since the vast majority of company cars are purchased new, this will only have a limited impact on company car purchases.

In other words, anticipation effects and the second hand market will not fundamentally change the results we present here.

The general ban on the sale of combustion engine cars within the European Union[14] from 2035 onwards will of course have the effect that only electric cars will be sold.

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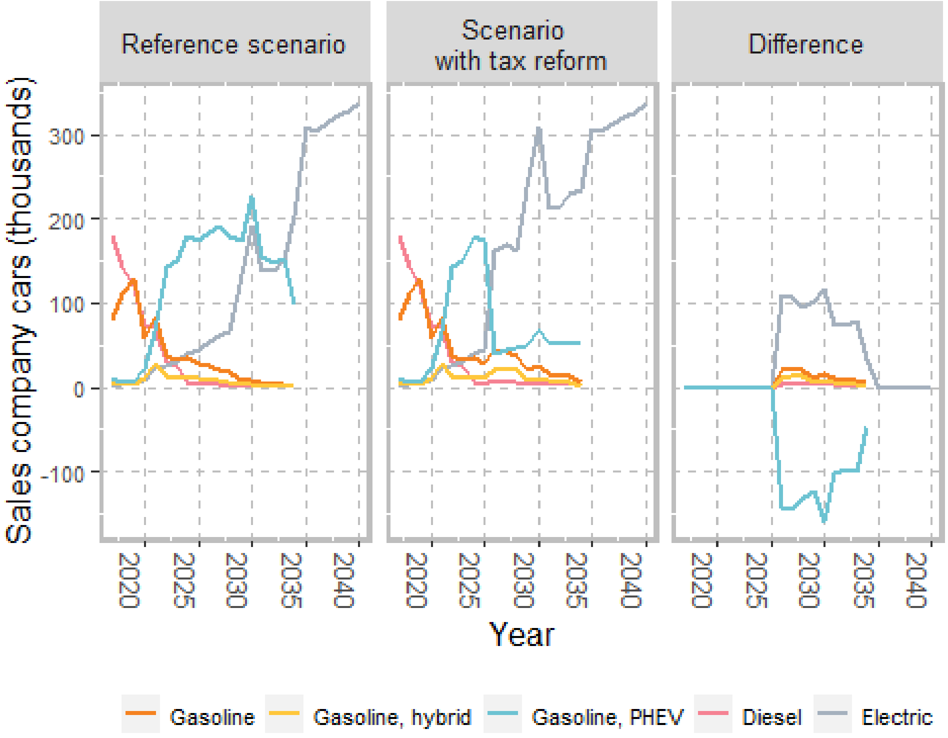
[14] Strictly speaking, cars with CO_2 emissions higher than zero

Here, too, anticipation effects may come into play. If, for example, people estimate that (taking into account the usage patterns of their cars) electric cars will still have a higher life cycle cost in 2035 than combustion engine cars, they might purchase of ICE cars in the period before the ban. Since company cars are generally used more intensively than cars owned by private individuals, it is unlikely that this effect will play a major role for company cars.

In the scenario with tax reform, the main effect is a very sharp decline in sales of gasoline PHEVs from 2026 onwards, mainly to the benefit of electric cars[15], but also (to a more limited extent) in favour of gasoline cars. This requires a word of explanation.

Graph 18 **Projections of the sales of new company cars with recalibrated categorical variables**



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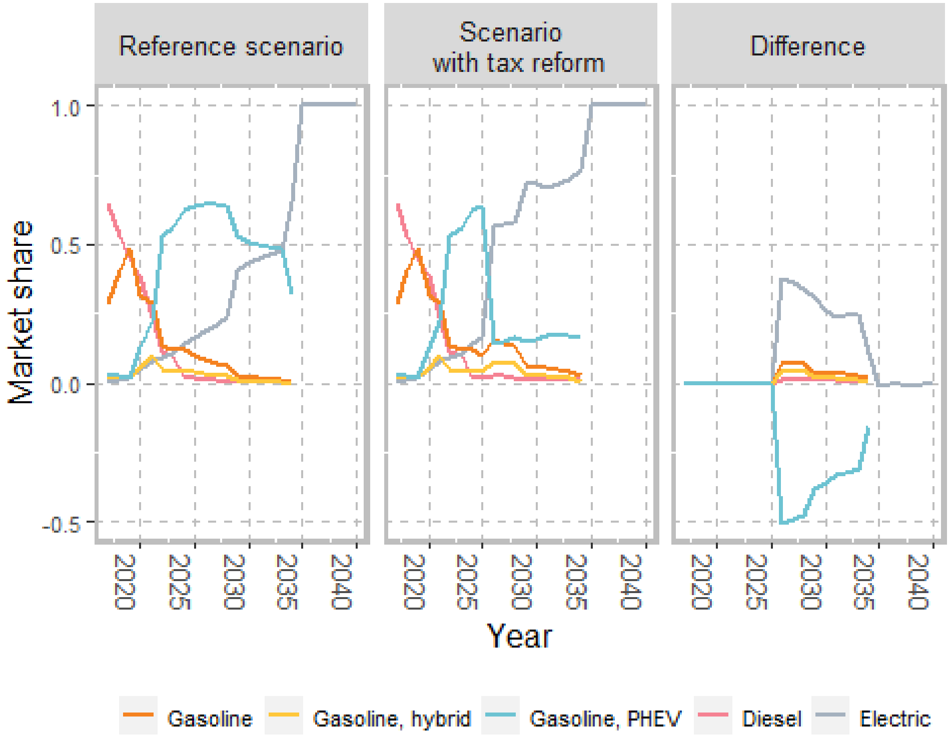
[15] Note also that even after 2035 there remains a small difference in the number of electric cars sold between the two scenarios: this results from the fact that different engine types have different survival functions. A change in the composition of new purchases thus indirectly affects the total number of cars scrapped each year, and thus also the total number of cars bought new.

Graph 19 Projections of the market share of new company cars with recalibrated categorical variables



This limited substitution effect can be better understood by looking at Table 19 and Table 20.

In a separate paper, we have calculated the life cycle cost of cars sold on the Belgian market. Table 19 and Table 20 show the average percentage change in the life cycle cost of company cars due to the tax reform in 2026 and 2031 respectively.

Table 19 Average percentage change in the life cycle cost of company cars due to tax reform (2026)

cartype	Small	Medium	Big
CNG	7	7	NA
dies	7	8	6
dieshybr_cs	NA	12	NA
dieshybr_phev	NA	18	20
electric	6	7	8
gas	5	6	5
gashybr_cs	NA	10	9
gashybr_phev	20	21	23
LPG	5	NA	NA

Table 20 Average percentage change in life cycle cost of company cars due to tax reform (2031)

cartype	small	medium	big
CNG	7	7	NA
dies	7	8	6
dieshybr_cs	NA	12	NA
dieshybr_phev	NA	18	20
electric	11	12	15
gas	5	6	5
gashybr_cs	NA	10	9
gashybr_phev	20	21	23
LPG	5	NA	NA

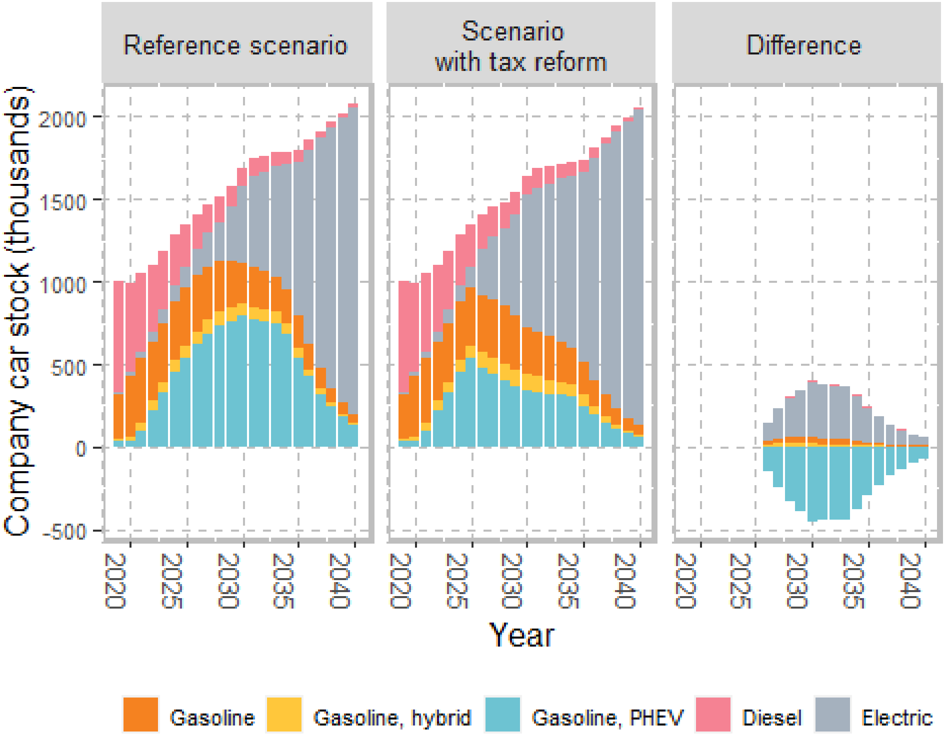
Abolishing the deductibility of non-electric company cars in the corporate income tax leads to an increase in life cycle cost for all engine types, but the effect is particularly large for PHEVs. Under the current scheme, PHEVs enjoy a very large deduction due to their low CO_2 emissions (at least, according to the test cycle) - for the PHEVs the disappearance of the tax deductibility thus has a much higher impact than for cars with (according to the test cycle) much higher CO_2 emissions.

The reduced deductibility of electric cars also leads to an increase in their life-cycle cost. This deductibility decreases further until 2031, and eventually the percentage increase in TCO is even higher for electric cars than for combustion engine cars.

This explains why there is also a substitution effect from PHEVs to petrol cars - bear in mind, however, that this effect is much smaller than the substitution in favour of electric cars.

The impact of the change in the composition of sales on the car fleet is much more gradual (Graph 20) – bear in mind that the composition of the fleet is influenced not only by changes in the composition of new purchases but also by access restrictions in the Brussels Capital Region.[16].

Graph 20 Projections of the company car stock with recalibrated categorical variables



The rapid increase in the total number of company cars is also noteworthy. This is due to the significant increase in the share of company cars in total sales in recent years. Company cars now account for more than 50% of total sales. However, this does not translate into a 50% share of the fleet, as company cars (and especially leased cars) are withdrawn from circulation faster[17] than privately owned cars. The net effect is a steady increase in the share of company cars in the total fleet – see Graph 21.

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[16] From 2030 for all cars with diesel technology, and from 2035 for all cars with petrol technology

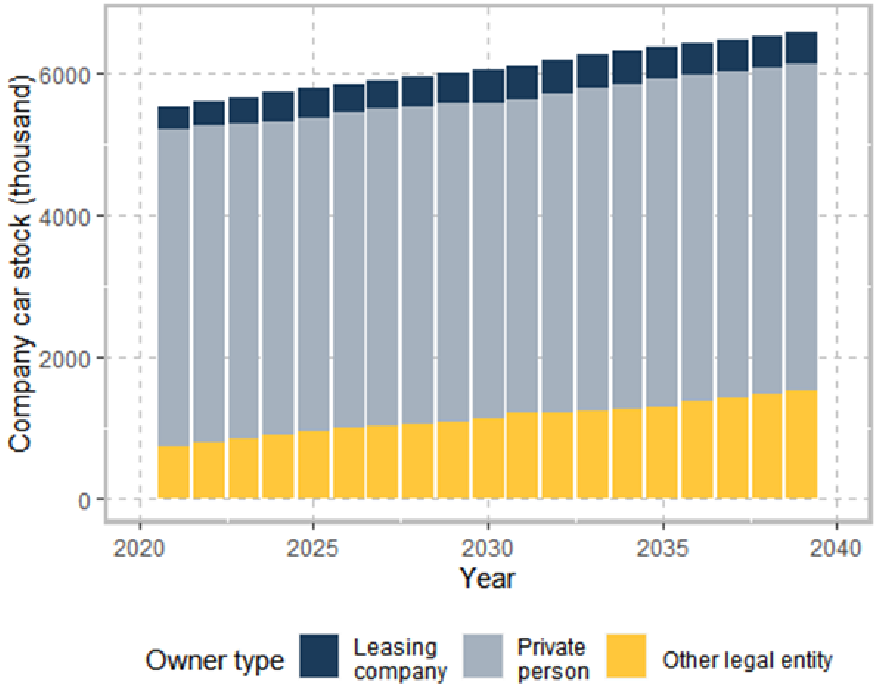
[17] Or resold to individuals.

Due to the rapid renewal of the commercial vehicle fleet, changes in the composition of sales also translate relatively quickly into changes in the composition of the fleet: by 2040, the commercial vehicle fleet will be almost entirely electric.

The main effect of the tax reform is a much faster decline of the fleet of gasoline PHEVs, especially in favour of fully electric cars.

As a result of the European ban on the sale of new cars with combustion engines from 2035 onwards, the difference between the two scenarios gradually decreases from then on.

Graph 21 Composition of the company car stock according to the owner type



4.2. Impact on tax revenues

We now turn to the impact of the tax reform on tax revenues. These effects consist of (see Graph 24):

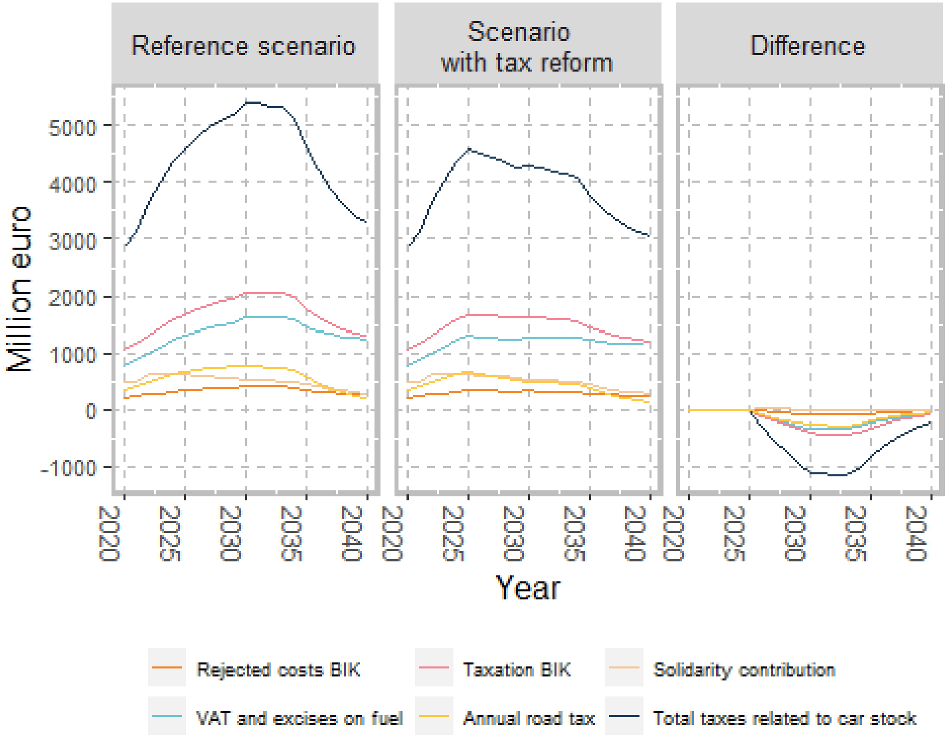
- the tax revenue determined by the ownership and use of company cars
- the lost revenue due to the tax deductibility of the acquisition of company cars
- the VAT on the purchase of new company cars
- the registration tax

We will now take a detailed look at the various components. We will first look at the tax receipts determined by the possession and use of company cars: (a) excise duties and VAT on the consumption of fuel and/or electricity[18] (b) the solidarity contribution to social security (c) the tax on the benefit in kind in the income tax (d) the share of the benefit in kind offered to employees that are non-deductible expenses for corporate taxation.

Since all these taxes depend on the total consumption of energy[19]. or of the CO_2 emissions per km of cars, a faster electrification of the car fleet is expected to lead to a decrease in that revenue – this is confirmed in Graph 22.

As shown in the right panel of Graph 22, the total revenue foregone as a result of the tax reform peaks at around €1 billion, mainly due to reductions in receipts from the tax on the benefit in kind and from excise duties on fuel and electricity. Thereafter, the difference between the two scenarios gradually diminishes as a result of the European ban on the sale of new cars with combustion engines.

Graph 22 Projection of the tax revenues linked to the ownership and use of company cars



The effect on revenue foregone due to the tax deductibility of car purchases is somewhat more complex.

First, the expected sharp increase in sales of gasoline PHEVs in the years before the tax reform comes into force leads to a significant increase in foregone corporate tax revenues: from less than €1 billion per year in the current situation to almost €4 billion per year in 2030. After that, with some delay, the foregone revenues for electric cars will also increase rapidly to more than EUR 2 billion annually. As a result

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[18] Note that until December 31, 2021, no excise tax was levied on electricity, but a so-called "federal contribution … to finance some public service obligations and the costs associated with regulating and monitoring the electricity and natural gas markets" - see https://www.creg.be/nl/a-z-index/federale-bijdrage.

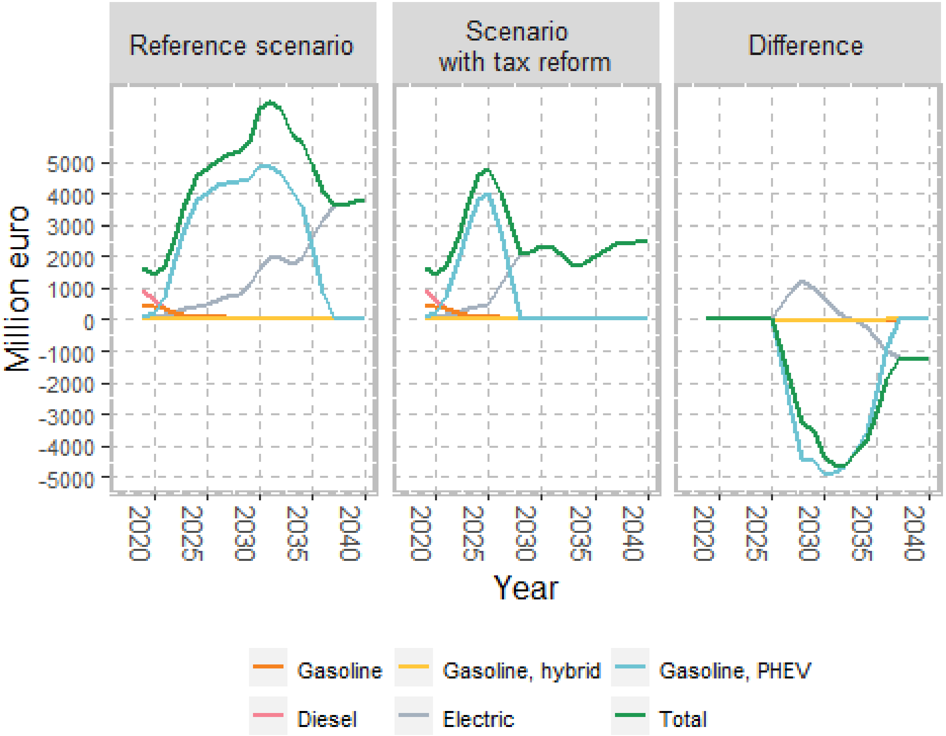
[19] In particular, excise duties and VAT on the consumption of fuels and electricity. For the annual consumption, we used the estimates of the annual kilometres travelled per cartype that are published annually by the FPS Mobility and Transport

of the tax reform, revenue losses for all car models except all-electric ones drop to zero from 2026 onwards.

For electric cars, however, the total effect on tax expenditures is not *a priori* determined: the tax deductibility per car decreases (leading to lower tax expenditures), but also leads to increased sales of electric cars (leading to higher tax expenditures). In the first few years of the reform, the second effect dominates, as shown in Graph 23[20], but that will change around 2030. After the entry into force of the European ban on the sale of new cars with combustion engines, only the first effect remains. In the long run, tax expenditures due to the tax reform decrease by about 1 billion euro.

However, the total tax expenditure after the reform still remains much higher than at the beginning of the model period: it increases from €1.4 billion in 2020 to approximately €2.4 billion by 2040.

Graph 23 Projection of foregone corporate tax revenues due to the deductibility of car costs



Graph 24 gives an overview of the total impact of the tax reform – note that in this graph, a decrease in tax revenue foregone is presented as an increase in tax revenue.

The tax reform leads to a significant increase in corporate tax revenues: about €1 billion annually in a stable situation (due to the reduced deductibility of electric cars), peaking at about €3.5 billion in 2031 – don't forget, however, that against the *current* situation there is still a significant increase in tax expenditures due to the increase in electric car sales.

The other important effect is the decrease in tax revenues from the ownership and use of company cars.

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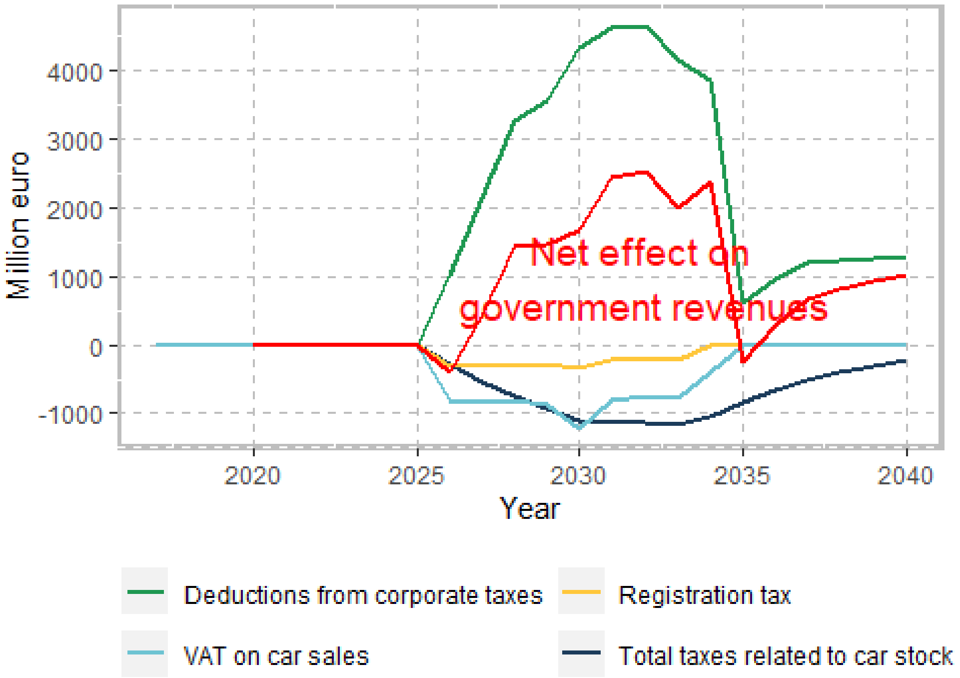
[20] We assume that tax depreciation takes place over a three-year period - so it takes three years each time to see the full effect of a change.

The reform also leads to a decrease in VAT revenue on car sales. The effect on the VAT is very small. These effects are reduced to almost zero from 2035 onwards.

The overall effect of the reform is an increase in annual net revenue of about 1 billion from 2026 onwards, except in 2026 and 2035, when the revenue lost from owning and using company cars is slightly higher than the increase in corporate tax revenue.

Graph 24 Net effect of the tax reform on tax revenues

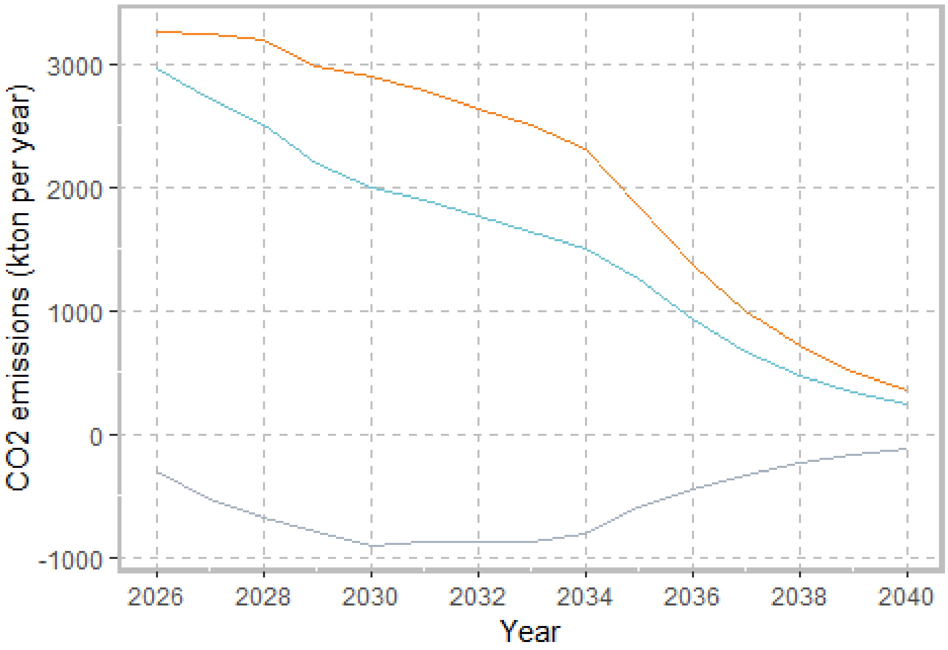


4.3. Impact on CO_2 emissions

The effect on CO_2 emissions is summarised in Graph 25.

Both without and with reform, emissions from the company car fleet decrease very rapidly after 2034. The big difference lies in the years between 2026 and 2035, where the tax reform clearly leads to an accelerated decline in CO_2 emissions, peaking at about 1 million tonnes of CO_2 annually in the first half of the 2030s.

Graph 25 Net effect of the tax reform on CO_2 emissions from the company car fleet



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6. Annex A: Key datasets

6.1. The IHS dataset

There are a number of websites where one can look up information regarding the price and technical characteristics of individual cars, such as vroom.be and autogids.be. However, such data often relate only to the current sales conditions of the base model. This means that the IHS Markit database is much richer than such freely available data in at least two ways:

- The data are reported not only at the level of brand-model combinations (e.g., Volkswagen Arteon), but down to each individual “version” of the model (e.g., Arteon 1.5). For some important characteristics of a car (such as cylinder volume), the differences between individual versions of a given model can be significant - sometimes by up to a factor of two.
- The IHS database covers all sales between 2000 and 2019 (for the model estimate we limited ourselves to the period 2012-2019, see below).

The following information is contained in the data set:

- The country and year of the sales
- The Make, Model, Sub-model and Version of each car
- The body type
- The fuel type
- The engine volume (when applicable) in cc, the engine maximal power (in Kw), the number of cylinders (when applicable), the transmission type, the number of driven wheels and the gross vehicle weight
- The generation of the car
- The price in EURO
- The number of cars sold

A car is uniquely defined by its version name, fuel type, body type, generation, power and weight. One “unique” car can sometimes be sold at different prices in one single year. In that case, we have summed the sales over the year and taken the average price (weighted for sales).

For electric cars, we have added the cost of a home charger to the purchase price.

We have excluded some body types (recreational vans, van buses, combi vans) that are clearly not meant to be used as passenger cars.

For cars with a combustion engine, we follow the COPERT classification to define the size classes: “small” cars have an engine size of less than 1400 cc, “medium” cars have an engine size between 1400 and 2000 cc, and “big” cars have an engine size exceeding 2000 cc. This classification will be useful for emissions reporting. We have also split full electric cars in three size classes, with thresholds at 20 and

70 kWh battery size – those thresholds are a bit arbitrary, as will be seen – but they do not affect the results, only the way of reporting them.

We have grouped some categories of body types to reduce the dimensionality of the problem: convertible, family cars (grouping hatchbacks, sedans, monospaces and wagons),all LDVs that are intended for a dual use as car, sport cars (coupe and roadsters), and SUVs (including pickup trucks intended for a dual use as car).

The dataset contains 31108 observations for 21629 individual cars.

A limitation of the IHS database is that there is no breakdown of the observations by region and type of owner. However, this breakdown does exist in the DIV database, which in turn does not contain price data. A direct merging of the IHS and DIV databases proved impossible because the commercial name in the DIV database often had no counterpart in the version names in the IHS database.

We therefore calculated the distribution by region and type of owner in each year for the entire 2012-19 period by car brand, engine type, and by decile of cylinder size[21]. We then broke down total sales for each car in the IHS database according to these ratios.

6.2. The dataset of the European Environment Agency

Some parameters determining the taxes (the engine volume and the Euro class) are contained in the IHS dataset or straightforward to calculate. This is not the case with the CO_2 emissions.

CO_2 emissions of newly registered cars are publicly available from the website of the European Environment Agency [22].

Note that these are the emissions according to the test cycle. For the estimation of the demand model, those are more relevant than the COPERT emissions:

- The purchase tax and annual road tax are based on the CO_2 emissions according to the test cycle
- It seems likely that, in deciding which cars to purchase, consumers will be guided by the test cycle fuel consumption, which is reported for each individual car and is easy to interpret (even if it may differ substantially from fuel consumption in real world driving conditions).

We must bear in mind that, certainly in the case of plug-in hybrid cars, the emissions in real driving conditions can be considerably higher than according to the test cycle (Plötz et al 2022).

In the European Environment Agency (EEA) dataset, a car is identified by its manufacturer’s name (e.g. FIAT group), type approval number (E4*2007/46*1410*01), type (MX), variant (JHVFV), version (K5LE1C), brand (JEEP) and trade name (COMPASS).

We have used data for 2012 to 2019. The dataset does not have a separate category for CS hybrid cars.

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[21] For full electric cars, using cylinder size as a criterion is obviously impossible, and we limited ourselves to brand as a criterion

[22] https://www.eea.europa.eu/data-and-maps/data/co2-cars-emission-18

A direct merge of the IHS and the EEA database turned out to be impossible, as the commercial name provided in the EEA had often no counterpart in the version names in the IHS database.

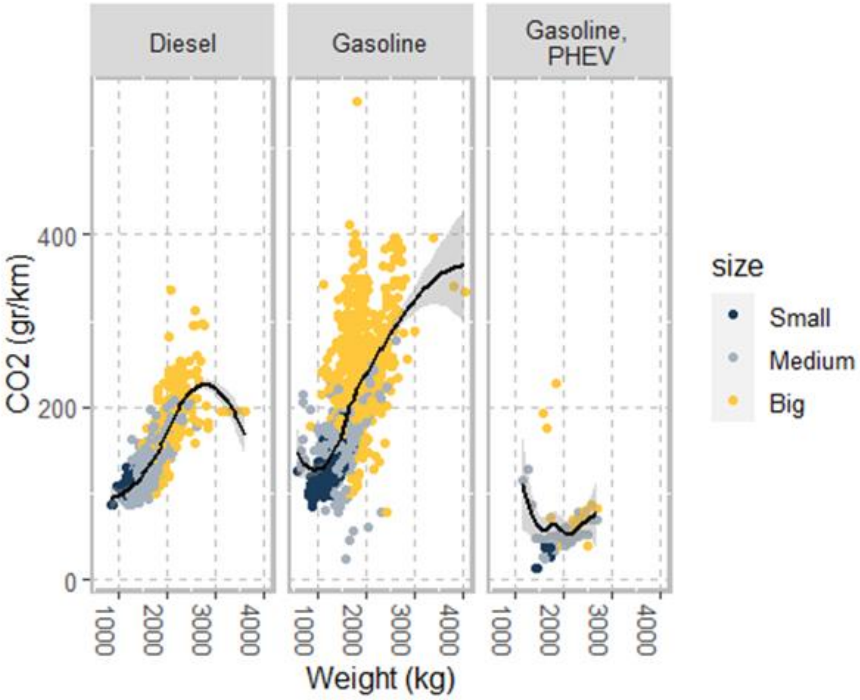
Instead, we have used the EEA database to construct a predictive model for a car's CO_2 emissions, which was then applied to the IHS database. There are four shared variables in both databases: the car's fuel, its maximum power, its engine size and its weight.

An indication of the predictive value of each variable is given in the scatterplots of Graph 26, Graph 27 and Graph 28. We have limited the graphs to the three main engine types: diesel, gasoline, and gasoline PHEVs. All other things being equal, CO_2 emissions from gasoline and diesel cars are an increasing function of power, engine size, and weight. Note the very large spread for gasoline cars. There are also some notable outliers in the case of diesel.

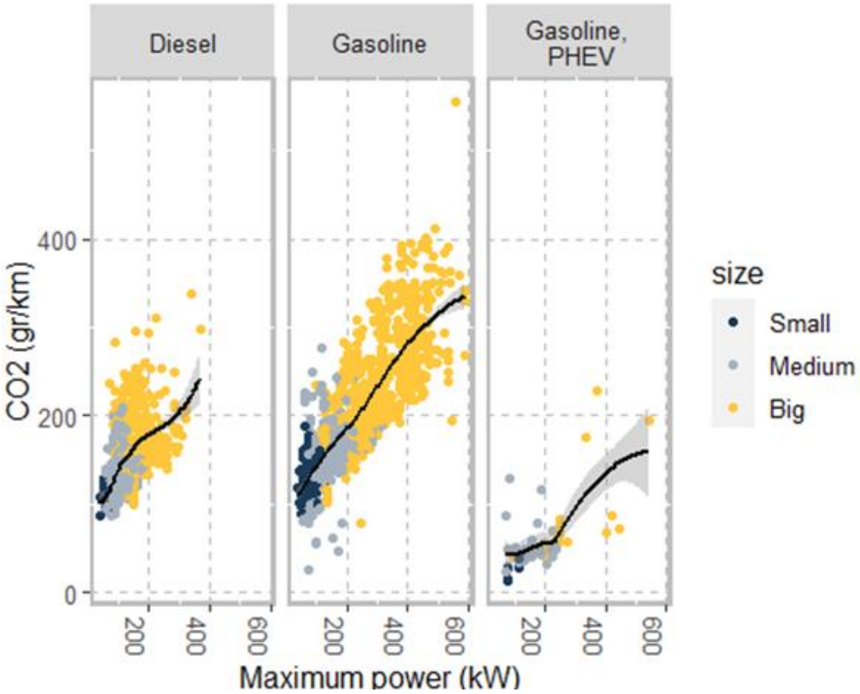
For gasoline PEVs, the situation is less clear, especially when it comes to the relationship between weight and CO_2 emissions-a complicating factor in the case of gasoline PEVs are the outliers.

One element that also explains the large spread for the relationship between a car's weight and its emissions are the sports cars, which tend to be very powerful but not heavy.

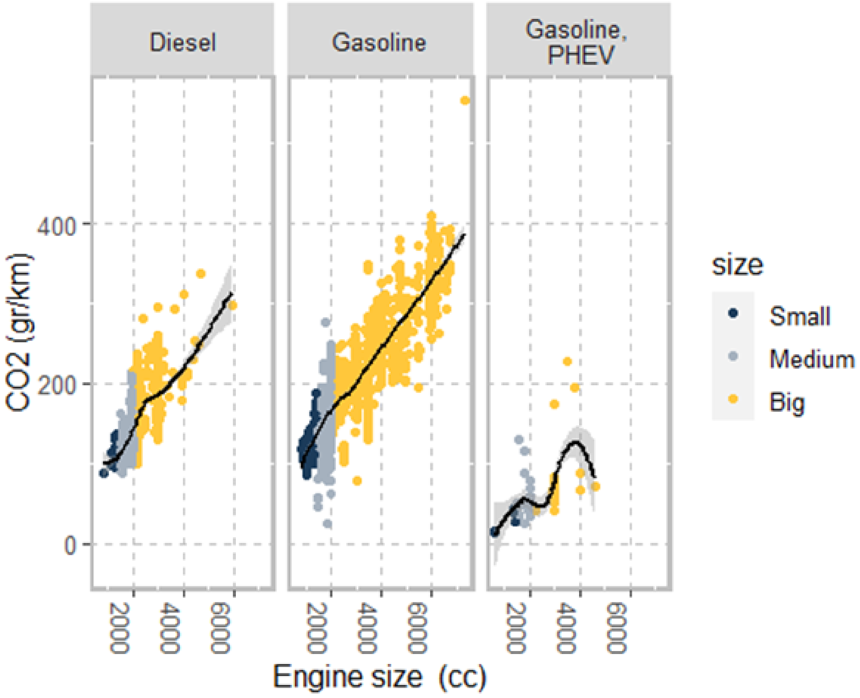
Graph 26 CO_2 emissions according to the NEDC test cycle versus weight (2010-2019)



Graph 27 CO$_2$ emissions according to the NEDC test cycle versus maximum power (2010-2019)



Graph 28 CO$_2$ emissions according to the NEDC test cycle versus engine size (2010-2019)



As can be seen from Tabel 21, a very simple model using the fuel type, the car's maximum power, weight, engine size and year of first registration almost perfectly forecasts CO$_2$ emissions according to the NEDC test cycle.

All coefficients are highly significant and have the expected sign: (a) all other things being equal, a higher engine power, weight and engine size lead to higher CO_2 emissions (b) all other things being equal, CO_2 emissions are the highest for LPG and gasoline cars, and the lowest for diesel PHEVs.

Tabel 21 OLS-model for CO_2 emissions according to the NEDC test cycle

	Model 1	
Kw	0.157 ***	(0.001)
gas	86.500 ***	(0.225)
LPG	40.697 ***	(4.061)
dies	69.846 ***	(0.271)
dieshybr_phev	68.828 ***	(1.782)
gashybr_phev	26.916 ***	(0.452)
cc	0.051 ***	(0.000)
Wght	-0.022 ***	(0.000)
I(Wght^2)	0.000 ***	(0.000)
gas:cc	-0.042 ***	(0.000)
LPG:cc	-0.003	(0.003)
dies:cc	-0.046 ***	(0.000)
dieshybr_phev:cc	-0.098 ***	(0.001)
gashybr_phev:cc	-0.078 ***	(0.000)
r.squared	0.987	
adj.r.squared	0.987	
df	14.000	
nobs	1785115	

*** $p < 0.001$; ** $p < 0.01$; * $p < 0.05$.

Tabel 21 gives the model results for CO_2 emissions based on the WLTP test cycle. As with the model for the NEDC test cycle, all coefficients are highly significant, and have the expected sign.

Tabel 22 OLS-model for CO_2

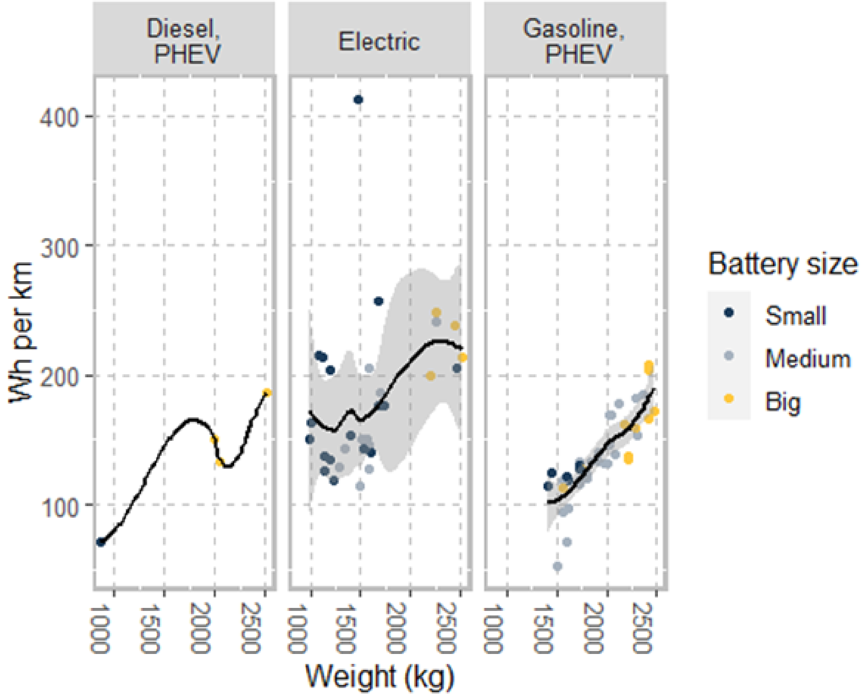
	Model 1	
Kw	0.199 ***	(0.001)
gas	118.386 ***	(0.457)
CNG	109.401 ***	(1.591)
Dies	99.617 ***	(0.574)
dieshybr_phev	-27.209 *	(13.377)
gashybr_phev	55.433 ***	(0.954)
Cc	0.092 ***	(0.001)
Wght	-0.034 ***	(0.001)
I(Wght^2)	0.000 ***	(0.000)
gas:cc	-0.090 ***	(0.001)
CNG:cc	-0.103 ***	(0.001)
dies:cc	-0.090 ***	(0.001)
dieshybr_phev:cc	-0.105 ***	(0.007)
gashybr_phev:cc	-0.140 ***	(0.001)
r.squared	0.991	
adj.r.squared	0.991	
Df	14.000	
nobs	524401	

*** $p < 0.001$; ** $p < 0.01$; * $p < 0.05$.

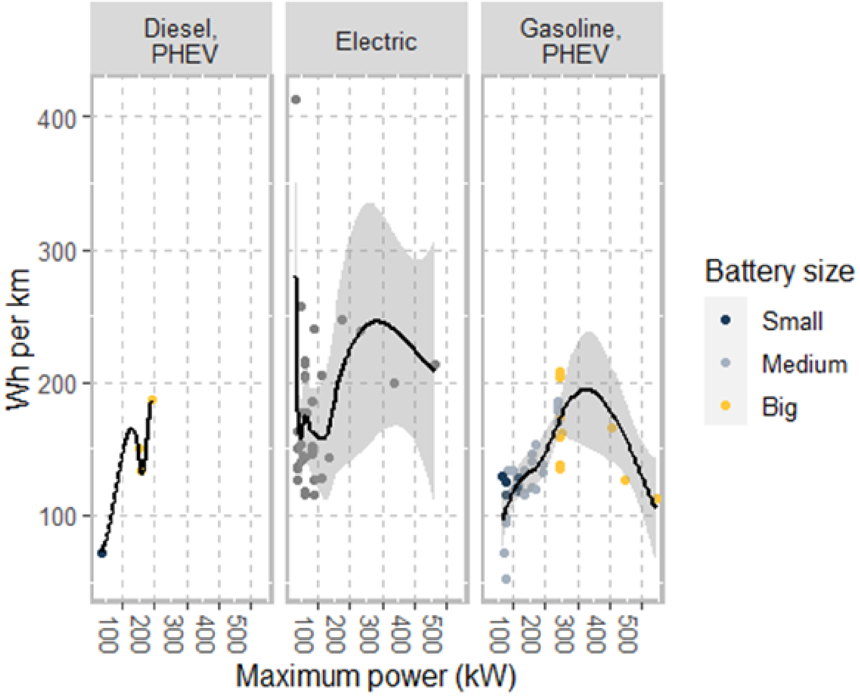
The approach to estimating the electrical energy consumption of electric cars and PHEVs is somewhat more complicated. Given the still relatively small number of models involved, a manual match between the IHS and EEA databases was possible for most models. For the remaining models, we used the same approach as for the CO_2 emissions of ICE cars.

From the scatterplots of Graph 29 and Graph 30, it is clear that the relationship between energy consumption per km and car weight and battery power is not as clearcut as for internal combustion engine cars. Also, the number of observations for diesel PHEVs is very small.

Graph 29 **Electricity consumption versus weight (2011-2019)**



Graph 30 **Electricity consumption versus maximum power (2011-2019)**



As can be seen from Tabel 23, a very simple model using the fuel type, and a cubic function of the car's maximum power and its weight, in combination for dummy variables for a limited number of makes, almost perfectly forecasts the car's electricity consumption.

Except for the coefficient for a car's power, all coefficients are highly significant: (a) There is no straightforward interpretation for the coefficients of the cubic functions of the weight and power (b) All other things being equal, electricity consumption is the highest for fully electric cars, and the lowest for diesel PHEVs

Tabel 23 OLS model voor het elektriciteitsverbruik van elektrische auto's en PHEV's

	Model 1	
cartypedieshybr_phev	86.52022 *	(36.47246)
cartypeelectric	127.09879 ***	(36.95326)
cartypegashybr_phev	86.22813 *	(37.62175)
Kw	-0.47532 **	(0.17692)
KwSq	0.00169 *	(0.00068)
KwCub	-0.00000 *	(0.00000)
Wght	0.00462	(0.04428)
WghtSq	0.00002	(0.00001)
r.squared	0.96281	
adj.r.squared	0.96184	
df	8.00000	
nobs	315	

*** $p < 0.001$; ** $p < 0.01$; * $p < 0.05$.

7. Annex B: The BLP approach to discrete choice modelling: summary

One limitation of our current data set is that the observed choices cannot be linked to individual household data. However, it is still possible to estimate discrete choice models from aggregate data only.

In this section, I subsequently explain how to do this with multinomial logit (MNL) and nested logit models. For reasons I will explain below, I have not pursued any of these approaches. However, it is still useful going through their principles, as a stepping stone to understanding the BLP approach that was effectively implemented.

7.1. Logit

In a logit model without individual-specific variables, the utility for consumer i if he chooses product j in a year t, is given by:

$$U_{ijt} = X_{jt}\beta + \xi_{jt} + \epsilon_{ijt}$$

where X_{jt} is a $1 \times k$ vector of product characteristics at time t, β is a $k \times 1$ vector of coefficients, ξ_{jt} is an unobservable characteristic at time t and e_{ijt} is the error term.

In the logit model, it is assumed that ϵ_{ijt} is distributed independently and identically Type I (or Gumbell) Extreme Value.

Under these assumptions, the probability that consumer i chooses product j in a given year t is

$$P_{ijt} = \frac{X_{jt}\beta + \xi_{jt}}{\sum_k X_{kt}\,\beta + \xi_{kt}}$$

Now take an arbitrary product with index $j = 1$ as reference product. Take the log of the expression above for all $j = 1, \dots, J$ and obtain

$$\ln(P_{ijt}) - \ln(P_{i1t}) = (X_{jt} - X_{1t})\beta + \xi_{jt} - \xi_{1t}$$

If the sample is large enough and representative, the law of large number implies (where S_1 and S_j are the observed market shares for product 1 and j, respectively):

$$\ln(S_{1t}) - \ln(S_{jt}) = \xi_{1t} + (X_{1t} - X_{jt})\beta - \xi_{jt}$$

The variables xi_{jt} and β can now be estimated with Ordinary Least Squares (OLS), and we can calculate both own- and cross-price elasticities for all products. Thus, the discrete choice model can be estimated, even if the only available information consists in market shares, prices and nonprice attributes for all products.

Usually, in this formulation, the reference good is the "outside" good: the option not to purchase any good. The "market share" of the "outside" good is taken as the difference between the potential demand in a given market and total actual purchase. In the case of the car market, the "potential demand" is usually defined as proportional to the total population, but the proportionality factor is the researcher's choice.

There are however some well-known drawbacks to this simple approach.

First, the model does not take into account the heterogeneity of consumers: "the size of the car is probably more important to households with many members than to smaller households. Low-income households are probably more concerned about the purchase price of a good … than higher-income households" (Train, 2009, p 50).

On top of those observable characteristics, households also differ according to characteristics that are not measured or that are even immeasurable ("unobserved heterogeneity"). As argued by Train (2009, p 52), even if the choice data can be linked to household characteristics, with unobserved heterogeneity, there is no guarantee "that a logit model will approximate the average tastes".

A second problem, is that if the characteristics of one good (say, its price) change all substitutes are treated equally, while one would expect that sales would be more sensitive to changes in the prices of close substitutes. To take the example from Train (2009, p 57): suppose that the government introduces a subsidy for the purchase of small electric cars. The logit model implies that the choice probability for large gasoline cars would drop by the same percentage as the choice probability for small gasoline cars. This is clearly not realistic.

A third issue is there are numerous attributes of the car (its comfort and the beauty of its design, for instance) that are not observed by the researcher (or cannot be measured objectively), but that do affect its price through at least two channels: (a) those unobserved attributes can be costly to the manufacturer, and the manufacturer will try to pass this cost on to the consumer (b) if those unobserved attributes are valued by the consumer, he will be willing to pay more for the car (Train, 2009, p. 315).

OLS will then lead to inconsistent estimates of the price parameter. For instance, if a high price also reflects unmeasured desirable attributes (such as a beautiful design), the impact of a price increase on demand will be mitigated through those attributes.

The nested logit model, in combination with Instrumental Variables, can address the second and the third issue, and we now turn to it.

7.2. Nested logit

In this section, I discuss how nested logit models can be estimated from market data without observed household characteristics. Examples of previous studies of car demand using this approach include Adamou et al. (2011), Berry (1994), Mayeres and Vanhulsel (2017) and Verboven (1996). In what follows, I follow the presentation in Adamou et al. (2011).

We have J products (cars), that can be divided in $G+1$ exhaustive and mutually exclusive groups, indexed by g. Each of those $g = 0,1,\dots,G$ can be further divided in H_g subgroups, each indexed by h_g. In the problem we consider here, group 0 corresponds to the outside option of not buying a car. $1,\dots,G$ could correspond to the body types of the cars, while the subgroups could correspond to the fuel - we will later come back to other possible specifications. For the sake of simplicity, I leave out the time index.

The utility of each consumer i from consuming product j is:

$$u_{ij} = \delta_j + \mu_{ij}$$

where δ_j is the mean utility (averaged over all consumers) and μ_{ij} is an individual specific term.

Mean utility is a function of price p_j, a j-dimensional vector x_j of observed attributes of the car (such as its weight and power), and an unoberved (to the researcher) component ξ_j:

$$\delta_j = x_j\beta - \alpha p_j + \xi_j$$

In the nested logit specification, the individual specific term can be written as:

$$\mu_{ij} = v_{ig}^1 + (1-\sigma_2)v_{igh}^2 + (1-\sigma_1)\epsilon_{ij}$$

where v_{ig}^1 is the utility consumer i derives from consuming a product in group g, and v_{igh}^2 is the utility consumer i derives from consuming a product in subgroup h of group g. ϵ_{ij} is the idiosyncratic preference of consumer i for product j. σ_1 and σ_2 are to be estimated parameters.

It can be shown that this framework implies (see Adamou et al. for a formal proof):

$$\ln(S_j) - \ln(S_0) = x_j\beta - \alpha p_j + \sigma_1 \ln(S_{j/h}) + \sigma_2 \ln(S_{h/g}) + \xi_j$$

where S_j and S_0 are the observed market shares for product j and the outside good 0, respectively; $S_{j/h}$ is the share of product j in subgroup h and $S_{h/g}$ is the share of all products of subgroup h in group g. As shown by McFadden (1978), a nested logit model with two nests is only consistent with random utility maximisation if $0 \leq \sigma_2 \leq \sigma_1 \leq 1$.

The parameters β, α, σ_1 and σ_2 can now be estimated directly from observed market shares, without knowledge of the characteristics of individuals.

Now that the discrete choice problem has again been reduced to a linear model, we can also address the endogeneity issue with the use of instrumental variables (IV). We will postpone the discussion of the IV we have used to Section 7.3.3.

Let us just mention here that we have estimated two nested logit specifications with two nest levels

- In the first approach the upper nest corresponds to the body type, and the lower nest to the fuel type
- In the second approach the upper nest corresponds to the fuel type, and the bodytype the lower nest.

We have estimated those models jointly for all years in 2015-19, and for each year separately.

None of those approaches was satisfactory. First, in most specifications, the condition $0 \leq \sigma_2 \leq \sigma_1 \leq 1$ does not hold, and the model is thus incompatible with individual rationality. Second, even if some year-specific model yielded a reasonable fit at the level of COPERT classes, the estimated relation had a very low predictive value for the other observed years. In other words, we have found no specification that was stable throughout time.

We could have envisaged other specifications for the nest structure, but, given the sheer infinity of specifications that are conceivable, we have shifted our focus to the approach pioneered by Berry, Levinsohn, and Pakes (1995) (henceforth BLP). This will also help us address the first issue mentioned above: taste heterogeneity.

7.3. Estimation with random coefficients (BLP approach)

In the BLP approach, the utility consumer n derives from product j in year t, is specified as follows:

$$U_{njt} = \overline{V}(p_{jt}, x_{jt}, \overline{\beta}) + \tilde{V}(p_{jt}, x_{jt}, s_n, \tilde{\beta}_n) + \xi_{jt} + \epsilon_{njt}$$

where p_{jt} is the price of product j in year t, x_{jt} is the vector of *observed* nonprice attributes, $\overline{\beta}$ is a vector of coefficients that is the same for all the consumers, s_n is a vector of demographic characteristics of the consumer (if available), $\tilde{\beta}_n$ is a vector of coefficients that vary over consumers, ξ_{jt} represents the average utility consumers obtain from the *unobserved* attributes of the product (at least, unobserved by the econometrician), and ϵ_{njt} is iid Type I Extreme Value. In other words, $\overline{V}(.)$ represents the observed utility that varies over years and products, but is the same for all consumers, while $\overline{V}(.)$ represents observed utility that also varies over consumers.

This term can be re-arranged as follows:

$$U_{njt} = [\overline{V}(p_{jt}, x_{jt}, \overline{\beta}) + \xi_{jt}] + \tilde{V}(p_{jt}, x_{jt}, s_n, \tilde{\beta}_n) + \epsilon_{njt}$$

For a given year and product, the term between the brackets is thus the same for all consumers, and is denoted as follows:

$$\delta_{jt} = \overline{V}(p_{jt}, x_{jt}, \overline{\beta}) + \xi_{jt}$$

The model can now be specified as:

$$U_{njt} = \delta_{jt} + \tilde{V}(p_{jt}, x_{jt}, s_n, \tilde{\beta}_n) + \epsilon_{njt}$$

where δ_{mj} is a constant term for each product and market, that can be estimated along with the parameter $\tilde{\beta}_n$. The remaining error term ϵ_{njt} is not correlated with the explanatory variables, and the endogeneity problem has been resolved.

This means that the initial problems has now been split in two steps:

- Estimating δ_{jt} and $\tilde{\beta}_n$

– Once δ_{mj} has been estimated, estimating $\overline{\beta}$

7.3.1. Estimating the constants and the variation of tastes

The BLP approach builds on the mixed logit (ML) model. ML resolves two issues with the logit model: taste heterogeneity and unrealistic substitution patterns.

In general terms, a ML model can be defined as *any* model where the choice probabilities (for decision maker n and alternative i) can be expressed as (see Train 2009, Chapter 6):

$$P_{ni} = \int L_{ni}(\beta).f(\beta).d\beta$$

where $L_{ni}(\beta) = \frac{e^{V_{ni}(\beta)}}{\sum_{j=1}^{J} e^{V_{nj}(\beta)}}$ (the logit probability evaluated for parameters β), $V_{ni}(\beta)$ is utility as a function of β and $f(\beta)$ is a density function.

As summarized by Train, the "mixed logit probability is a weighted average of the logit formula evaluated at different values of β, with the weights given by density $f(\beta)$".

If the "mixing" distribution is discrete, the mixed logit model reduces to the "latent class model", where the weights correspond to the shares in the population of each "segment" with distinct choice behaviour or preferences. With continuous distributions, the β can be interpreted as coefficients that vary over utility-maximizing decision-makers according to density $f(\beta)$. Moreover "(v)ariations in taste that are related to observed attributes of the decision-maker are captured through specification of the explanatory and/or the mixing distribution."

If one assumes that the density follows a normal distribution, the modelling thus entails the estimation of the means of the β and their co-variance matrix. However, the modeller can choose any suitable distribution.

As explained by Train (2009, Chapter 6), a ML model can be interpreted as "representing error components that create correlations among the utilities for different alternatives". Given that the nested logit model is one special case of correlated error components (where error components are correlated within each nest), the ML model is more general than the NL model.

Let us now come back to the representation of the aggregate choice model we discussed above. If we use θ to denote the parameters that describe the density of β, then the mixed logit probabilities are:

$$P_{nit} = \int \frac{e^{\delta_{it}+\tilde{V}(p_{it},x_{it},s_n,\tilde{\beta}_n)}}{\sum_{j=1}^{J} e^{\delta_{jt}+\tilde{V}(p_{jt},x_{jt},s_n,\tilde{\beta}_n)}}.f(\beta|\theta).d\beta.$$

Following Nevo (2000), we can implement this as follows. Assuming that there are K observable non-price characteristics for each car, x_{jt} is a $1 \times K$ vector, and $\tilde{\beta}_n$ is a $(K+1) \times 1$ vectors. Then:

$$\tilde{\beta}_n = \Pi\ D_n + \Sigma\ v_n$$

where D_n is a $d \times 1$ vector of (observable) demographic variables, Π is a $(K+1) \times d$ matrix of coefficients (to be estimated) that indicate how the taste parameters vary with those observable demographics, Σ is a $(K+1) \times (K+1)$ matrix of parameters (to be estimated) and v_n is a $(K+1) \times 1$ vector representing unobserved heterogeneity. Furthermore, v_n is assumed to follow a parametric distribution, and D_n follows either a nonparametric distribution obtained from other data sources or an estimated parametric distribution.

As explained by Nevo (2000), even without observing the demographic characteristics of the individuals who made the transactions, we can still have information about the *distribution* of their characteristics, such as their family's income or the number of the children. The vector v_n refers to individual characteristics that can affect the choice of a car but whose distribution is not known (Nevo refers to "owning a dog" to illustrate this point).

The combination of demographics D_n, unobserved heterogeneity v_n and product specific error terms ϵ_{njt} that will lead to the choice of product j is then:

$$A_{jt}(X_t, P_t, \Delta_t; \theta_2) = \{(D_n, v_n, \epsilon_{n0t} \dots, \epsilon_{nJt}) | U_{njt} \geq U_{nlt} \text{ for } l = 0,1, \dots, J\}$$

where $X_t = (x_{1t}, \dots, x_{Jt})'$, $P_t = (p_{1t}, \dots, p_{Jt})'$ and $\Delta_t = (\delta_{1t}, \dots, \delta_{Jt})'$ are the matrices with the observed non-price characteristics, prices and mean utilities for all cars at time t, and $\theta_2 = (\Pi, \Sigma)$ are the estimated parameters.

The estimated market share of car j at time t is then given by:

$$\begin{aligned} s_{jt}(X_t, P_t, \Delta_t; \theta_2) &= \int_{A_{jt}} dP^*(D, v, \epsilon) \\ &\qquad \text{(applying Bayes' rule)} \\ &= \int_{A_{jt}} dP^*(\epsilon | D, v)\ dP^*(v|D)\ dP^*(D) \\ &\qquad \text{(assuming independent distributions)} \\ &= \int_{A_{jt}} dP^*(\epsilon)\ dP^*(v)\ dP^*(D) \end{aligned}$$

If the integral in this expression would have a closed-form solution, then the application of maximum likelihood methods to estimate θ_2 and Δ_t would be straightforward. This is for instance the case if ϵ is iid Type I extreme value, and if v_n and D_n follow a degenerate univariate distribution.

In general, this will not be the case, and we will have to work with a approximation to the integral by first taking random draws from the distribution of v and D, and then solving the integral analytically for ϵ. As discussed by Nevo, solving the integral analytically for ϵ for given values of v and D is preferable to taking random samples for ϵ.

An additional complication is that there is a separate δ_{jt} that needs to be estimated for each single car and each year. A numerical estimation of these constants will often be numerically unfeasible.

Therefore, the following approach has been proposed by Berry (1994) and BLP (1995):

- The procedure starts with initial values for θ_2 and the δ_{jt}
- For these initial values, the predicted market share is calculated by taking random draws from the distribution of v and D. For each random draw, we solve the integral analytically for ϵ to obtain the choice probability. The predicted market share is then average of these choice probabilities.
- Each δ_{jt} is recalculated until the predicted market share is equal to the observed market share, using an iterative procedure to be explained below.

The initial values for θ_2 are usually given by random draws from given distribution. One possibility for the initial values of the δ_{jt} is to take the outcome of a nested logit estimation. (Note that, for the model we have estimated, taking $\delta_{jt} = 0$ as initial values works fine).

The δ_{jt} are adjusted as follows. Suppose the observed market share is S_{jm}. If, after iteration tau, the predicted market share is $\hat{S}_{jt}(\delta^{\tau})$, then δ is adjusted as follows:

$$\delta_{jt}^{\tau+1} = \delta_{jt}^{\tau} + \ln\left(\frac{S_{jm}}{\hat{S}_{jt}(\delta^{\tau})}\right)$$

This iteration is repeated until observed market shares equal predicted market shares (up to an approximation error).

Berry (1994) has shown that, for every value of θ_2 , this procedure will converge to a set of constants such that predicted shares equal actual shares. Moreover, BLP (1995) have demonstrated that this iterative process is guaranteed to converge to this unique set of constants.

In other words, there is a unique vector of δ_{jt} for any given value of θ_2. As explained by Train (2009, p 324), this means that the choice probability is a function of θ_2 alone: $P_{njt}(\theta_2) = P_{njt}(\Delta_t(\theta_2), \theta_2)$, and the log-likelihood function is given by $\Sigma_n \ln\left(P_{ni_nt}(\theta_2)\right)$ where i_n is n's chosen alternative.

This method thus combines maximum simulated likelihood (MSL) for the estimation of the θ_2 with "the contraction" algorithm for the estimation of the δ_{jt}.

Thus, if we have information on the distribution of demographic variables, Π can be estimated, even if the choice data cannot be linked with demographics of the individuals who have made the observed choices. If no information is available on the distribution of demographics, then only the parameters for unobserved heterogeneity can be estimated.

7.3.2. Estimating the parameters entering the constant

The next step is to estimate the parameters that explain the d_{jt}. If the model is linear in parameters, the following regression model needs to be estimated:

$$\delta_{jt} = \overline{\beta}' \, \overline{V}(p_{jt}, x_{jt}) + \xi_{jt}$$

Now, remember that ξ_{jt} represents the non-observable attributes of car j in year t, which is correlated with price.

This means that, in order to obtain consistent estimates of the parameters, we need to apply instrumental variables (IV) regression - we will come back below to the choice of the IV.

The IV estimator is the value of $\overline{\beta}$ that satisfies (where zjt is the vector of instrumental variables and $\widehat{\delta_{Jt}}$ is the estimated value of δ_{jt}):

$$\Sigma_j \Sigma_t \left[\widehat{\delta_{Jt}} - \overline{\beta}' \; \overline{V}(p_{jt}, x_{jt})\right] \; z_{jt} = 0$$

The closed form estimate of $\overline{\beta}$ is given by

$$\widehat{\overline{\beta}} = \left(\Sigma_j \Sigma_t z_{jt} \; \overline{V}(p_{jt}, x_{jt})'\right)^{-1} \; \left(\Sigma_j \Sigma_t z_{jt} \; \widehat{\delta_{Jt}}\right)$$

However, if the number of instrumental variables exceeds the number of parameters $\overline{\beta}$ to be estimated, then the system of equations is overidentified, and we resort to the Generalised Method of Moments (GMM) estimator instead.

To simplify notation, let $g_{jt} = \left[\widehat{\delta_{Jt}} - \overline{\beta}' \; \overline{V}(p_{jt}, x_{jt})\right] \; z_{jt}$. The moment conditions can then be written as $g = \Sigma_j \Sigma_t g_{jt} = 0$. The GMM estimator is given by the value of $\overline{\beta}$ that minimizes:

$$g' \; \Theta^{-1} \; g$$

where Θ is a positive definite weighting matrix. The optimal weighting matrix is given by the asymptotic covariance of g, $\Sigma_j \Sigma_t g_{jt} \; g_{jt}'$. Alternatively, we can assume homoscedastic errors (which is the approach taken in this paper).

In the current paper, $\Theta = Z^T * Z$, with $Z_t = [P_t; X_t; IV_t]$, where, as before, $X_t = (x_{1t}, \dots, x_{Jt})'$ and $P_t = (p_{1t}, \dots, p_{Jt})'$. IV_t represents all the instrumental variables that are not included in X_t.

Now let Z be the $Lx(J * T)$ matrix of all instrumental variables, let $Delta = (\Delta_1', \dots, \Delta_T')'$ be the \$ (J * T) x 1\$ vector of the common utility terms, $\overline{\beta}$ be $(K + 1)x1$ vector of linear parameters that need to be estimated, let $P = (P_1', \dots, P_n')$ be the $(J * T) * 1$ prive vector and let $X = (X_1, \dots X_t)$ be the $(J * T)XK$ matrix of exogenous linear variables.

We can then write:

$$g = Z * \left(\Delta - [P; X] * \overline{\beta}\right)$$

The GMM objective function becomes then:

$$\left(Z * \left(\Delta - [P; X] * \overline{\beta}\right)\right)' \Theta^{-1} \left(Z * \left(\Delta - [P; X] * \overline{\beta}\right)\right)$$

This can further be developed as:

$$\Delta' * Z' * \Theta^{-1} * Z * \Delta - \Delta' * Z' * \Theta^{-1} Z * [P; X] * \overline{\beta} - \overline{\beta}' * [P; X]' * Z' * \Theta^{-1} * Z * \Delta + \overline{\beta}' * [P; X]' * Z' * \Theta^{-1} * Z * [P; X] * \overline{\beta})$$

The first order conditions with respect to $\overline{\beta}$ are then given by:

$$-2 * \Delta' * Z'\Theta^{-1} * Z * [P;X] + 2 * \overline{\beta}' * [P;X]' * Z' * \Theta^{-1} * Z * [P;X] = 0$$

This yields the following analytical solution for $\overline{\beta}$:

$$([P;X]' * Z' * \Theta^{-1} * Z * [P;X])' * \overline{\beta} = (\Delta' * Z' * \Theta^{-1} * Z * [P;X])'$$

or (compare with Nevo (2000, Appendix, p 5):

$$\overline{\beta} = ([P;X] * Z * \Theta^{-1} * Z' * [P;X]')^{-1}[P;X]' * Z' * \Theta^{-1} * Z * \Delta$$

Given that Δ is itself a function of the non-linear parameters $theta_2$, in any iteration of the algorithm, $\overline{\beta}$ is thus completely determined by $theta_2$.

After calculating the GMM objective function for a given value of θ_2, the gradient of the objective function is calculated as Nevo (2000, Appendix, p 6):

$$\nabla = 2 * J^T * Z * \Theta^{-1} * Z^T * \xi$$

where $J = \frac{\partial \Delta_t}{\partial \theta_2}$ is the Jacobian of Δ_t with respect to θ_2.

7.3.3. The choice of the instrumental variables

On top of the observed nonprice attributes, we have used the approach proposed by BLP (1995) and used two types of instruments: (a) the average measured nonprice attributes of other cars of the same make (b) the average measured nonprice attributes of other makes. The underlying idea is that "each manufacturer will price each of its products in a way that takes consideration of substitution with its other products as well as substitution with other firms' products. For example, when a firm is considering a price increase for one of its products, consumer who will switch away from its products to another of the same firm's products do not represent as much of a loss (…) as consumers who will switch to other firms' products."

Additionally, we follow Grigolon, Reynaert and Verboven (2017) and use cost shifters as instruments. More specifically, we use the price of two important input materials (steel and oil), and multiply it with a car's weight (ideally, we would have the share of each input in a car's weight, but this information is not available). Aluminum and copper are also import input materials, but the correlation of their price with the price of steel is too high to add anything meaningful.

Finally, we have also used the cost per kwh for batteries.

7.3.4. In summary

- The procedure starts with initial values for θ_2 and the δ_{jt}
- For these initial values, the predicted market share is calculated by taking random draws from the distribution of v and D.
- Each δ_{jt} is recalculated until the predicted market share is equal to the observed market share (these are the “inner” iterations); there is a unique value of δ_{jt} for each θ_2.
- $\overline{\beta}$ is expressed as a function of $\Delta_t(\theta_2)$ and substituted in the GMM objective function.
- A gradient-based approach is used to find a new value of θ_2.
- This is repeated until a given convergence criterion is met.

8. Annex C: Indicators of the cost of company cars in CASMO

In the discrete choice model for private individuals, we take the following costs into account:

- The purchase price (including the registration tax)
- The annual road tax
- The cost of fuel consumption

For the other cost categories (maintenance, periodic inspection, insurance) we do not have data that are reliable enough on the level of individual models.

In this section we show that, compared to private car owners, additional elements play a role in the choice between different cars for companies. When estimating the purchase price, we have to take into account elements such as the corporate tax, the VAT deduction, the employer "solidarity contribution" to social security and the non-deductible expenses of the benefit in kind.

But in addition, by providing an employee with a company car free of charge at a favourable fiscal and parafiscal regime, a company can also save gross salary costs. In this paper, we calculate the capital cost and the salary cost savings associated with the purchase of a company car for a company that maximises its profits and thereby offers its employees a company car and salary in which the employees are at least as well off as with a higher gross salary without a company car.

We proceed as follows. First, we determine all the elements that determine the company's profit when it offers a company car with fuel card to its employees. Next, we look at how employees' utility and budget constraints are affected by the offer of a company car as a benefit in kind. Based on this, we determine what wage an employer can offer that is acceptable to the employee if a company car is made available to the employee. We use this result to derive the indicator variables used in the discrete choice model of CASMO.

8.1. Profits with a company car

We consider the most general case (i.e. both salary cars and "pure" service cars).

We consider the profit over the lifetime of the car (as a company car). Since this is short (three years according to Copenhagen Economics (2010)), we do not use annuities, but simply calculate the average over the years.

If the company car is a salary car, we assume that the benefit in kind consists of: (a) the provision of a car (b) a variable cost (in concrete terms, the fuel paid with the bank card provided by the employer).

The purchase price of the car is p_x. The total loss of value over the lifetime of the car is then $p_x - RV$ where RV is the residual value at the end of the lifetime. Following Copenhagen Economics (2010), we assume that a company car remains in service $n_{cc} = 3$ years and is then resold at 33% of its original value.

In what follows, we set the annual variable cost equal to the annual fuel consumption y, with market price p_y (including excise duties). In the first step, we look at the part of the profit that is independent of the cost of providing the company car. This can be calculated as follows:

$$(1-\tau_\pi).\left(R-w\ (1+\tau_{ssr})\right).$$

where

- R is the part of the annual gross profit that does not depend on the cost of labour and the company car;
- w is the annual gross salary;
- τ_{ssr} the employer's statutory social security contribution rate;
- τ_π the (marginal) corporate tax rate.

We assume that the total number of working hours is exogenous - we normalise it to 1. We also abstract from the heterogeneity of the workforce and assume that everyone receives the same remuneration.

The second component of the profit is the cost associated with making the car available to the employee, abstracting from VAT.

We need to consider following parameters:

- θ_x and θ_y are the share of the (respectively fixed and variable) car costs that can be deducted from the corporate income tax (75% for the fuel costs and, for all other costs, a percentage depending on fuel and CO_2 emissions, see further for more details).
- BIV is the registration tax, which can be deducted from the taxable profit.

So, over the lifetime, the net capital cost outside of VAT is $(1-\tau_\pi\theta_x)\ (p_x-RV+BIV)$, while the annual cost of fuel consumption net of VAT is $\left(1-\tau_\pi\ \theta_y\ \right)\ p_y\ y$.

The third component of profit is VAT. Φ, the deductible portion of VAT, is proportional to the professional use of the company car, unless that professional use is more than 50%, in which case $\varphi = 0.65$. Since we do not have data on the proportion of professional use, in CASMO we always assume $\varphi = 0.65$. We also assume that the VAT received on the sale of the car on the second-hand market is payable in full to the tax authorities.

Finally, there are two terms in the profit that are specific to salary cars:

- $H(p_x)$ represents the annual valuation of the benefit in kind by the tax administration if the car is made available free of charge for private use. This valuation depends on the CO_2 emission and on the purchase price p_x – we describe the calculation method in section 3.2.5. In total, for salary cars, $\tau_\pi\ \nabla(y)\ H(p_x)$ should be deducted from profit after tax, where $\nabla(y)$ is the percentage of "rejected expenses" in the benefit in kind – the exact percentage depends on whether fuel costs are reimbursed or not (see further for more details).

- T_{solr} is the annual solidarity contribution paid by employers for salary cars. This valuation depends on the CO2 emissions (see further for details)

So the average annual profit after tax is (where n_{cc} is the expected life and we assume that the car is depreciated linearly):

$$\begin{aligned} \Pi \quad = \quad & (1-\tau_\pi)[R - w_{cc}\ (1+\tau_{ssr})] \\ & -\frac{1}{n_{cc}}(1-\tau_\pi\theta_x)[(1+(1-\varphi)\ VAT)\ p_x + BIV - RV] \\ & -(1-\tau_\pi\theta_y)[1+(1-\varphi)\ VAT]\ p_y\ y - \tau_\pi\ \nabla\ H(p_x) - (1-\tau_\pi)\ \tau_{solr} \end{aligned}$$

8.2. The utility function for the employee

We assume that a potential employee is either working full-time or is unemployed. If he is unemployed, he receives the "reservation utility" $barU$, which is exogenously determined. As mentioned above, we normalise the number of hours worked to 1. A worker derives utility $U(x,y,c)$ from the consumption of both cars and other goods C. When the worker can use a company car with a fuel card for free, his budget constraint is:

$$C_{cc} = w_{cc}\ (1-\tau_{sse})\ (1-\tau_{inc}) - H(p_x)\ \tau_{inc}$$

w_{cc} is the annual gross salary for an employee with a salary car, τ_{inc} is the (marginal) income tax rate, τ_{sse} is the statutory employee contribution rate, and $H(p_x)$ is the valuation of the car by the tax administration (the benefit in kind).

If the employer does not offer a salary car, we consider the benefit of an employee who buys the same car and also pays the variable costs in full himself. For such employee the budget constraint is (where n_{pc} is the lifetime of a car purchased privately and w_{pc} is the annual gross salary for an employee without a salary car):

$$C_{pc} = w_{pc}\ (1-\tau_{sse})\ (1-\tau_{inc}) - (1+VAT)\ \left[\frac{1}{n_{pc}}\ (p_x - RV) + p_y\ y\right] - \frac{1}{n_{pc}} BIV$$

We are therefore abstracting from a possible tax deduction of commuting costs. Note also that a private person does not necessarily put a car on the second hand market as quickly as a firm. Therefore, we do not equate the lifetime of a car owned by a private person, n_{pc} , with n_{cc} a priori.

8.3. Gross salary for an employee with salary car

In what follows, we assume that the employer offers a single model as a salary car. In our formulation of the problem, we also assume that the number of kilometres travelled for private purposes, y, does not change when a salary car is made available by the employer. Clearly, this assumption underestimates both the benefits to the employee and the costs to the employer.

We also assume that the gross wage of an employee without a salary car and the price of the salary car are determined in a competitive market, and are a given for the employer. In that case, w_{cc} is the choice variable for the firm. w_{cc} will only be accepted if the utility for the employee is at least equal to the reservation utility and greater than the utility under an employment contract without salary car.

The employer is thus faced with a profit maximisation problem with two inequality constraints. The Lagrangian for the employer is then:

$$\mathcal{L} = \Pi + \mu \left\{U_{cc} - \overline{U}\right\} + \lambda \left\{U_{cc} - U_{pc}\right\}$$

Where U_{cc} is the utility with salary car, U_{pc} is the utility if the worker purchases the same car privately, $\overline{U}$ is the reservation utility for the worker, and $$ and λ are the Lagrange multipliers.

The first order conditions for the gross wage with salary car are:

$$\frac{\partial \mathcal{L}}{\partial w_{cc}} = -(1-\tau_\pi)\ (1+\tau_{ssr}) + \mu\ \frac{\partial U}{\partial C}(1-\tau_{sse}).(1-\tau_{inc}) + \lambda\ \frac{\partial U}{\partial C}\ (1-\tau_{sse})\ (1-\tau_{inc}) = 0$$

$$\mu\ \frac{\partial \mathcal{L}}{\partial \mu} = 0; \frac{\partial \mathcal{L}}{\partial \mu} = U_{cc} - \overline{U} \geq 0; \mu \geq 0$$

$$\lambda\ \frac{\partial \mathcal{L}}{\partial \lambda} = 0; \frac{\partial \mathcal{L}}{\partial \lambda} = U_{cc} - U_{pc} \geq 0; \lambda \geq 0$$

Suppose that $U_{cc} > U_{pc}$. $\mu\ \frac{\partial \mathcal{L}}{\partial \mu} = 0$ then implies that $U_{cc} = 0$. If also $U_{cc} > U_{pc}$, then $\lambda\ \frac{\partial \mathcal{L}}{\partial \lambda} = 0$ also implies that $\lambda = 0$. But then the first-order condition $\frac{\partial \mathcal{L}}{\partial w_{cc}} = -(1-\tau_\pi).(1+\tau_{ssr}) = 0$ can never be satisfied. Thus, it is impossible to have a profit-maximising solution if both $U_{cc} > \overline{U}$ and $U_{cc} > U_{pc}$.

If $U_{cc} > U_{pc}$, then $\lambda = 0$. Then $\frac{\partial \mathcal{L}}{\partial w_{cc}} = 0$ is possible only if $\mu > 0$ and therefore $U_{cc} = \overline{U}$. However, this means that $\overline{U} > U_{pc}$ and therefore the reservation utility is not attainable if no company car is offered. Since we do not have any data that would allow us to calculate $\overline{U}$, we are not going to consider this possibility further.

Thus, the only remaining situation is where $\mu = 0$ and $U_{cc} = U_{pc}$. Then it follows from $\frac{\partial \mathcal{L}}{\partial w_{cc}} = 0$ that:

$$\lambda.\frac{\partial U}{\partial C} = \frac{(1-\tau_\pi).(1+\tau_{ssr})}{(1-\tau_{sse})(1-\tau_{inc})}$$

And from $U_{cc} = U_{pc}$ (assuming p_x, p_y and y are the same for salary cars as for private cars):

$$\begin{aligned} &w_{cc}\ (1-\tau_{sse})\ (1-\tau_{inc}) - H(p_x)\ \tau_{inc} \\ &= w_{pc}.(1-\tau_{sse})(1-\tau_{inc}) - (1+VAT)\ \left[\frac{1}{n_{pc}}\ (p_x - RV) + p_y\ y\right] - \frac{1}{n_{pc}}\ BIV \end{aligned}$$

And so we obtain the following expression for the difference in wages with and without

$$w_{cc} = w_{pc} + \frac{H(p_x)\ \tau_{inc} - (1+VAT)\ \left[\frac{1}{n_{pc}}\ (p_x - RV) + p_y\ y\right] - \frac{1}{n_{pc}}\ BIV}{(1-\tau_{sse})\ (1-\tau_{inc})}$$

If $(1+VAT)\left[\frac{1}{n_{pc}}\ (p_x - RV) + p_y\ y\right] + \frac{1}{n_{pc}}BIV > H(p_x)\ \tau_{inc}$, then $w_{cc} < w_{pc}$. Note that the left-hand side of the first inequality is the annual cost of the car purchased privately, while the second is the taxes that the employee must pay on his in-kind benefit if the car is provided by the employer. This formula makes sense: if the employee can save money by accepting a salary car, then the employer can also offer him a lower gross salary.

To simplify the notation, we set: $AC_{PC}(n_{pc}) = (1 + VAT)\left[\frac{1}{n_{pc}}\ (p_x - RV) + p_y\ y\right] + \frac{1}{n_{pc}} BIV$.

$\frac{H(p_x)\ \tau_{inc} - AC_{PC}(n_{pc})}{(1-\tau_{sse})\ (1-\tau_{inc})}$ is the annual saving in net wages (that is, after deducting employees' social security contributions and income tax) made possible by the provision of a salary car.

Note that the wage cost savings depend on the car's lifetime: every time the car is offered as a salary car, the employee saves the purchase cost once, but he has to pay tax on the benefit in kind every year. The longer the car is in use, the smaller the relative importance of the saved purchase price compared to the tax on the benefit in kind, and thus the smaller the benefit to the employee compared to buying a private car. Substituting the formula for w_{cc} in Π, we get the following expression for the annual profits with company car:

$$\begin{aligned}
&(1-\tau_\pi).\left(R - \left[w_{pc} + \frac{H(p_x)\ \tau_{inc} - AC_{PC}(n_{pc})}{(1-\tau_{sse})\ (1-\tau_{inc})}\right]\ (1+\tau_{ssr})\right) \\
&-\frac{1}{n_{cc}}\ (1-\tau_\pi\ \theta_x)\ [(1+(1-\varphi)\ VAT)\ p_x + BIV - RV] \\
&-(1-\tau_\pi \theta_y)[1+(1-\varphi)\ VAT]\ p_y y - n_{pc}\ \tau_\pi.\nabla\ H(p_x) - (1-\tau_\pi)\ \tau_{solr}
\end{aligned}$$

The difference with the profits without salary car is:

$$\begin{aligned}
\Delta(\Pi) \quad = \quad & \frac{(1-\tau_\pi)\ (1+\tau_{ssr})}{(1-\tau_{sse})\ (1-\tau_{inc})}\left(AC_{PC}(n_{pc}) - H(p_x)\ \tau_{inc}\right) \\
&-\frac{1}{n_{cc}}\ (1-\tau_\pi\ \theta_x)[(1+(1-\varphi)\ VAT).p_x + BIV - RV] \\
&-(1-\tau_\pi\ \theta_y)[1+(1-\varphi)\ VAT]\ p_y\ y - \tau_\pi.\nabla\ H(p_x) - (1-\tau_\pi)\ \tau_{solr}
\end{aligned}$$

Note that $AC_{PC} > H(p_x)\ \tau_{inc}$ is a necessary but not a sufficient condition for $\Delta(\Pi) > 0$: the wage cost saved must be large enough compared to the direct financial cost of the salary car and the associated (para)fiscal burden.

8.4. Approach in the discrete choice model for CASMO

If we consider only the annual "accounting" cost of a salary carwe obtain the following expression for the fixed cost:s

$$FC_{SC} = \frac{1}{n_{cc}}\ (1-\tau_\pi\ \theta_x)\ [(1+(1-\varphi)\ BTW).p_x + BIV - RV] + \tau_\pi\ \nabla\ H(p_x) + (1-\tau_\pi)\ \tau_{solr}$$

In the formulation of the discrete-choice model, we replace the purchase price including registration tax (the indicator we use for private cars) with FC_{SC}\$. In addition, as for private individuals, there is also the cost of fuel consumption: $(1-\tau_\pi.\theta_y)[1+(1-\varphi)\ BTW]\ p_y y$.

But we have shown above that by providing a payroll vehicle, a company can also save labor costs. The annual labor costs saved (taking into account employer social security contributions and corporate tax deductions) are:

$$SS_{SC} = \left[AC_{PC}\left(n_{pc}\right) - H(p_x)\tau_{inc}\right] . \frac{(1-\tau_{\pi})\ (1+\tau_{ssr})}{(1-\tau_{sse})\ (1-\tau_{inc})}$$

Since this formula SS_{SC} is derived based on very specific assumptions, it is better to interpret it as an "indicator of the labor cost saving potential of a payroll vehicle."

In addition, we also note that FC_{SC} and SS_{SC} depend on the expected lifetime of the car (when owned by a company and/or by an individual, respectively), parameters that are not directly observable for an individual car. Since these parameters can vary greatly from car to car, and as a function of the socio-economic characteristics of the worker, we can conclude that the value of FC_{SC} is not fixed a priori. Some sensitivity analysis is therefore appropriate.

9. Annex D: Sensitivity analysis

9.1. Results with unchanged categorical variables

The results in section 4 are based on the assumption that the changes in the market shares of electric cars and PHEVs observed in 2020-21 reflect a fundamental trendchange. As explained in Section 3.6, this trend change is formalized in the model by recalibrating the categorical variables for the engine types.

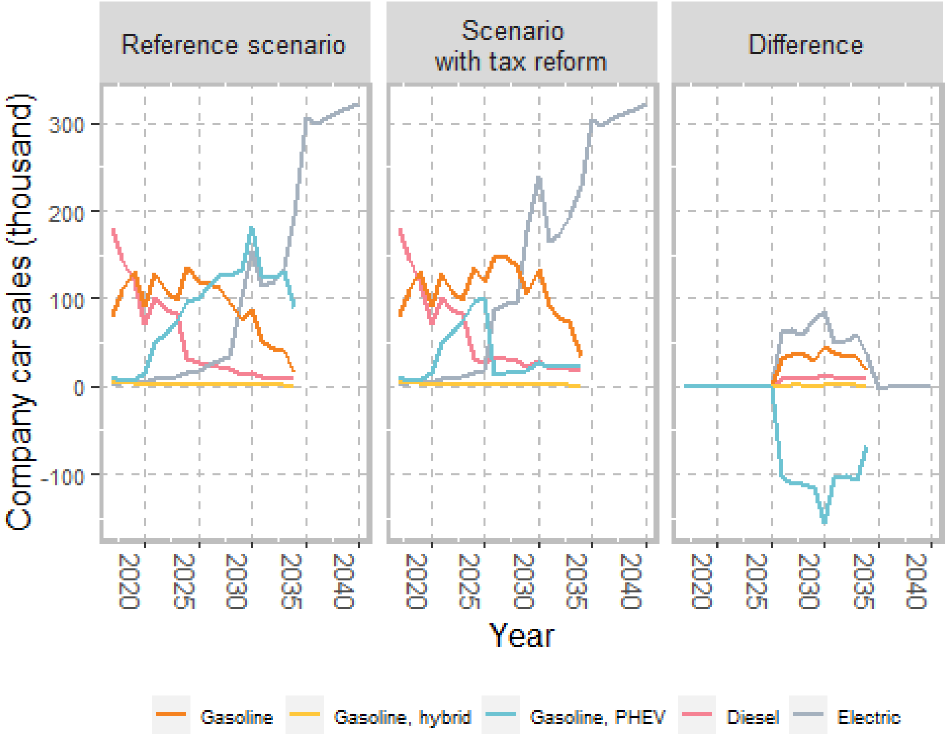
In this section, we examine the effect of the tax reform under the assumption that the observations in 2020-21 are only temporary changes, and that the market will return to "business as usual". Technically, this means that we do not recalibrate the categorical variables for the engine types to match the market shares in 2020-21.

As can be seen from a comparison of Graph 31 with Graph 18, the results are qualitatively similar to what we observed with the recalibrated model. The order of magnitude of the effects is also comparable.

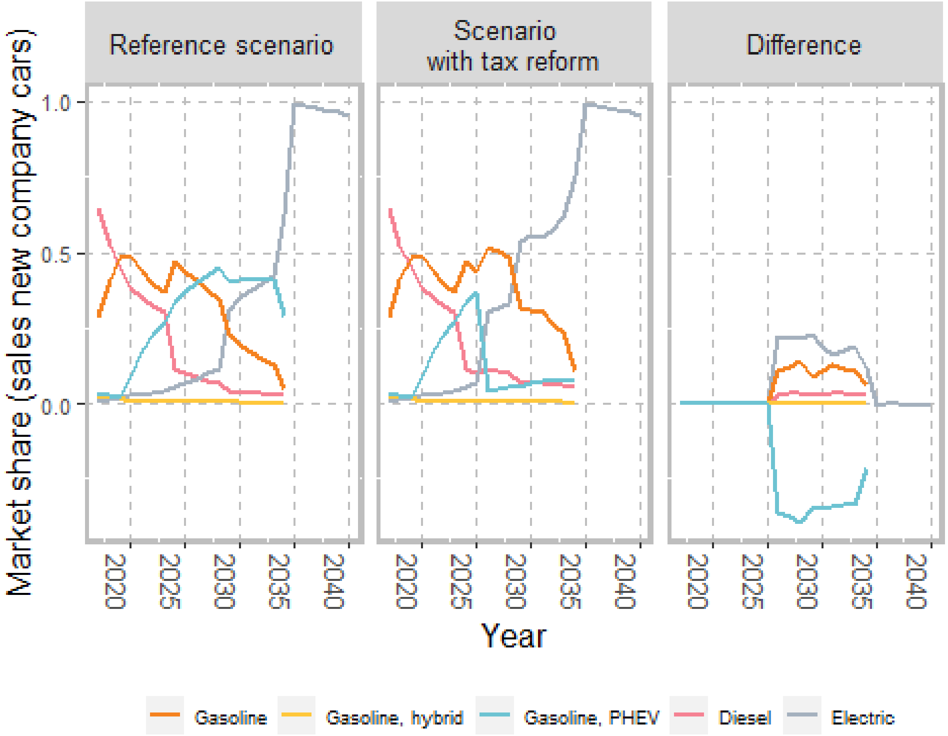
However, there are also some differences:

- In the reference scenario, sales of gasoline and diesel cars decrease less rapidly.
- In the reference scenario, the growth in the sales of electric cars is slower.
- In the scenario with the tax reform, sales of gasoline PHEVs decline less.
- The substitution effect in favour of electric cars is much less pronounced, but there is a larger substitution effect in favour of petrol and diesel cars.

Graph 31 **Projections of new company car sales with unchanged categorical variables**



Graph 32 **Projections of new company car market shares with unchanged categorical variables**



This is confirmed in Graph 33, in which we show the changes in sales compared to the recalibrated model. We present these changes both for the two scenarios, as for the difference between the two.

A return to "pre-2020 trends" would result in a larger market share for gasoline and diesel cars, and a smaller market share for electric cars and gasoline hybrids.

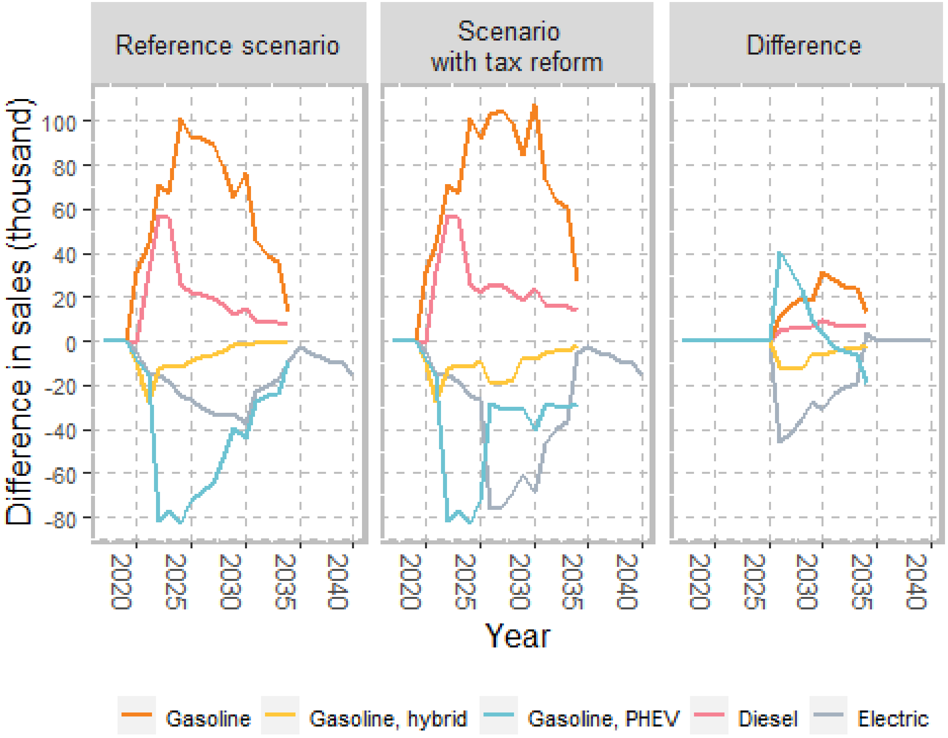
In the reference scenario, an additional 60,000 gasoline cars would be sold by 2026.

However, the largest difference is seen in the scenario with tax reform: around 2030, the market share for gasoline cars would be more than 80,000 cars higher with a return to pre-2020 trends. The right-hand panel confirms that the substitution effect due to tax reform is larger for gasoline cars and smaller for electric cars.

This implies that the size of the substitution effect due to the tax reform is sensitive to the value of the categorical variables for the engine types. In other words, it does indeed matter whether or not the sudden increase in sales figures for electric cars and PHEVs in 2020 and 2021 represents a fundamental trend change.

We should therefore also look at the impact on tax revenues.

Graph 33 **Impact on company car sales: difference with the recalibrated model**

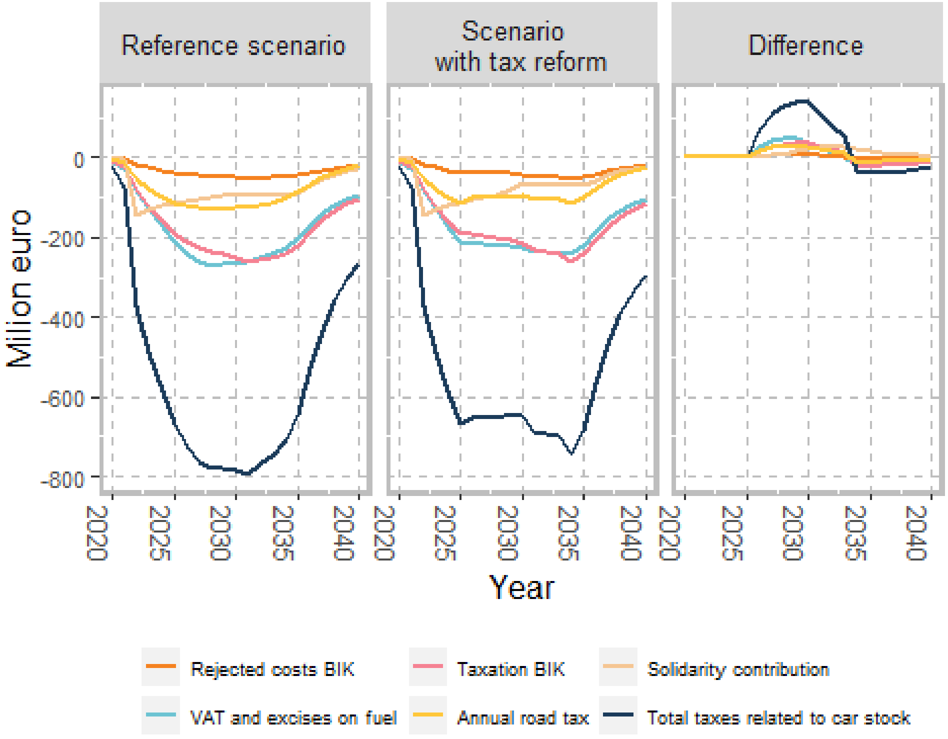


Let us first look back at the taxes on the use and ownership of company cars.

In Graph 34 we look at the difference in results between the model without and the model with recalibration of the categorical variables for the engine types. This shows that a return to pre-2020 sales trends would lead to a decrease in these tax revenues, both in the reference scenario and in the scenario with tax reform.

However, if we look at the total revenue, it appears that these differences are less than an order of magnitude of the total revenue. Moreover, the differences vary enormously from year to year. Since the impact on the composition of sales was relatively large, this relatively small effect on tax revenues requires some further explanation.

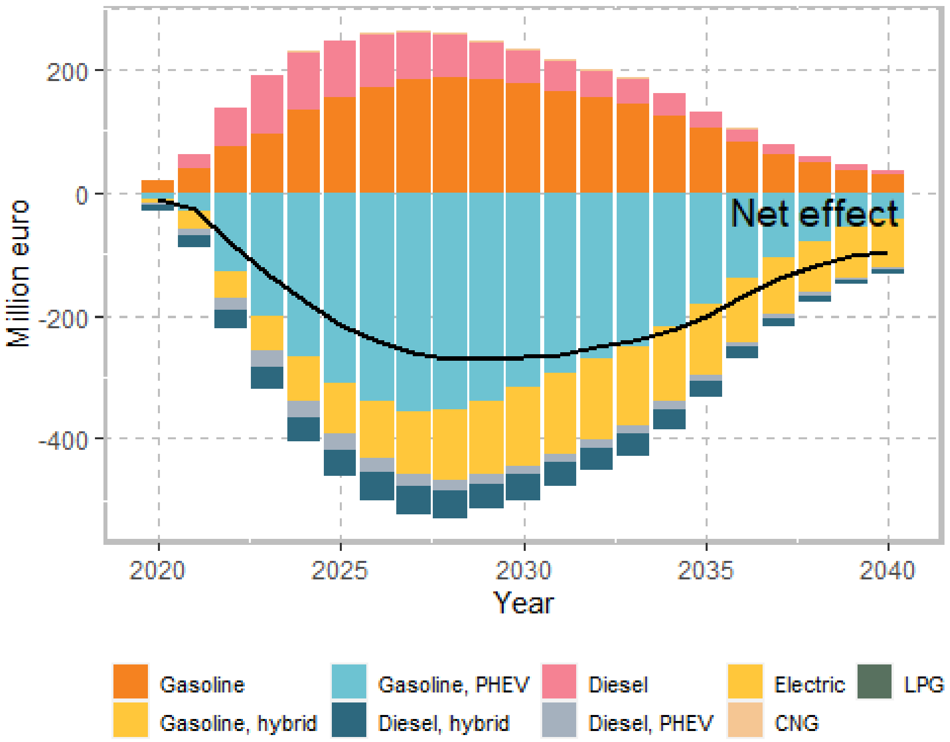
Graph 34 Projection of the tax revenues linked to the ownership and use of company cars: comparison with the results with recalibrated categorical variables



This can be better understood by zooming in on, for example, the excise duty and VAT revenues on energy consumption of the cars in the reference scenario, broken down by engine type. This shows that a continuation of the pre-2020 sales trends leads to higher excise duty revenues for gasoline and diesel cars, but to a decrease in revenues for electric and hybrid (whether or not PHEV) cars. The net effect is a small decrease.

All in all, we can say that continuing the pre-2020 sales trends makes relatively little difference to tax revenues from owning and using company cars, at least when compared to the effect of the tax reform.

Graph 35 **Impact on the revenues from excises and VAT on energy consumption: comparison with the reference scenario with unchanged categorical variables**

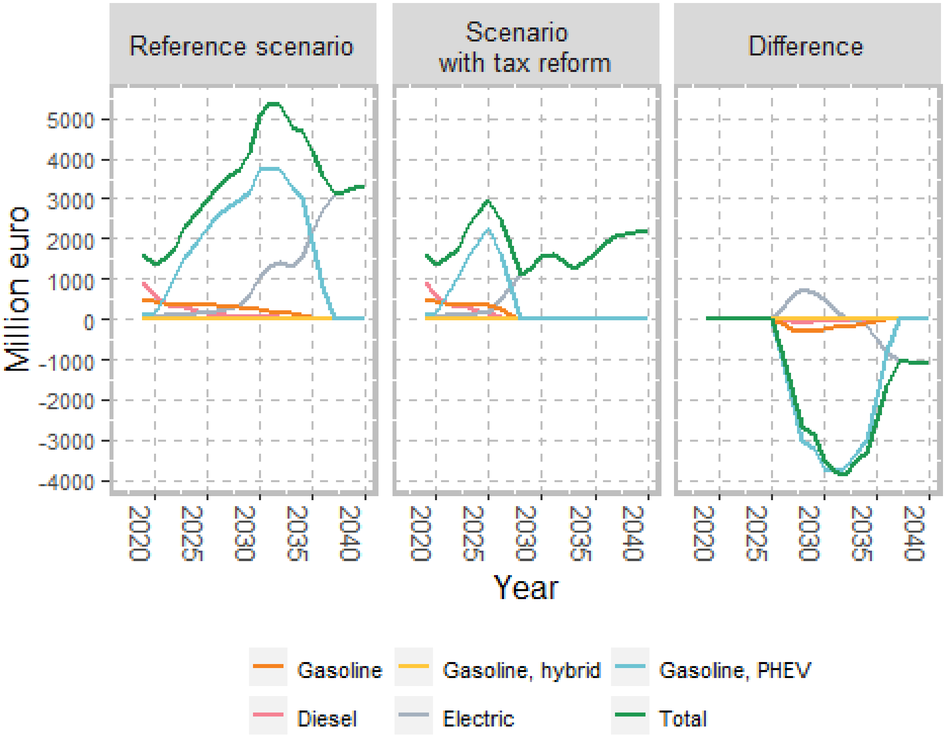


Compared to the projections we made with recalibrated categorical variables, a continuation of the pre-2020 sales trends in the reference scenario leads to a decrease in foregone corporate income tax revenues. This results from the lower sales figures for the engine types with the highest corporate income tax deduction: electric cars (which are 100% deductible in the reference scenario) and (until the end of this decade) gasoline PHEVs (which, thanks to their low CO_2 emissions, enjoy a large deduction according to the test cycle) (see Graph 36 and Graph 37).

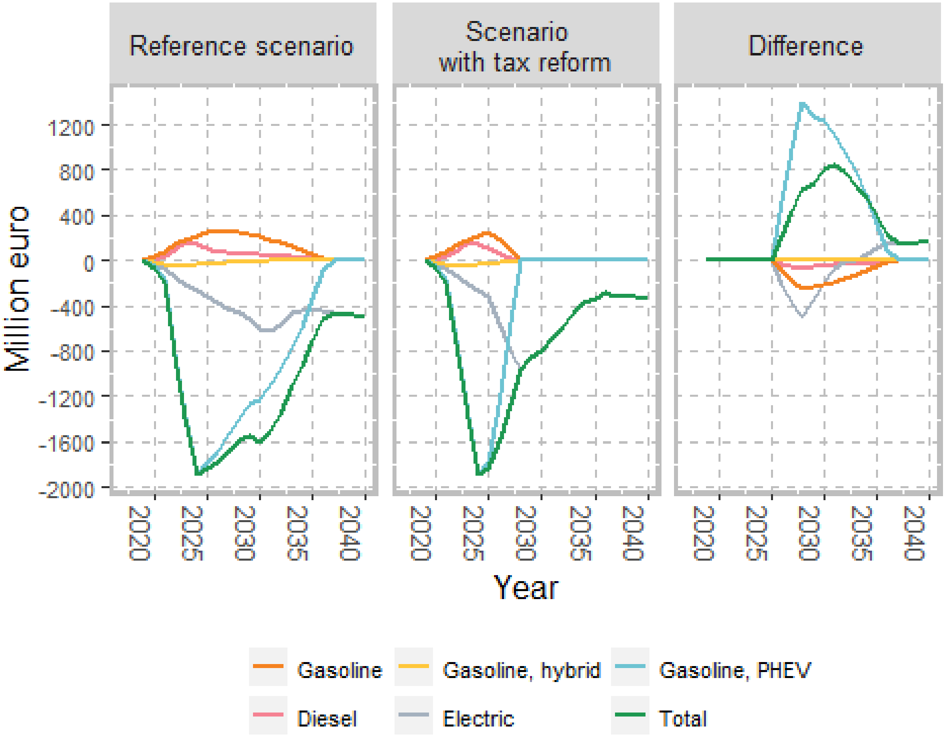
In the scenario with tax reform, the tax benefit for gasoline PHEVs disappears, but for electric cars it remains the case that a continuation of the pre-2020 sales trends leads to lower sales and thus to a decrease in lost revenues.

However, Graph 36 and Graph 37 also show that the impact of recalibrating the categorical variables for the engine types is limited to about 20% of the total revenues, and, above all, that the order of magnitude of the impact of the tax reform remains the same.

Graph 36 Impact on corporate income tax revenue with unchanged categorical variables



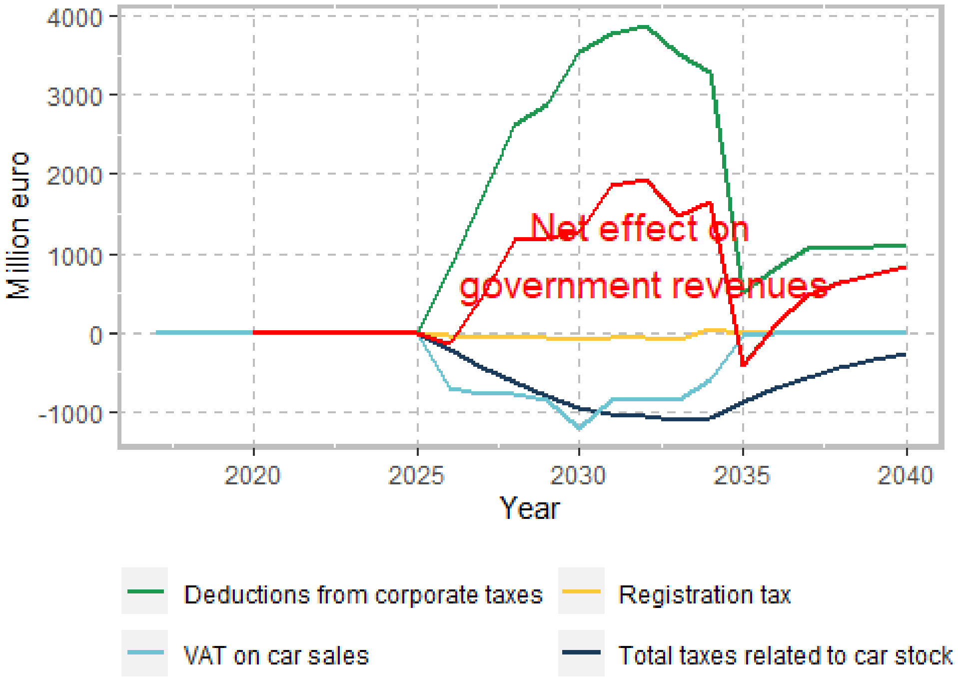
Graph 37 Impact on corporate income tax revenue: comparison with recalibrated categorical variables



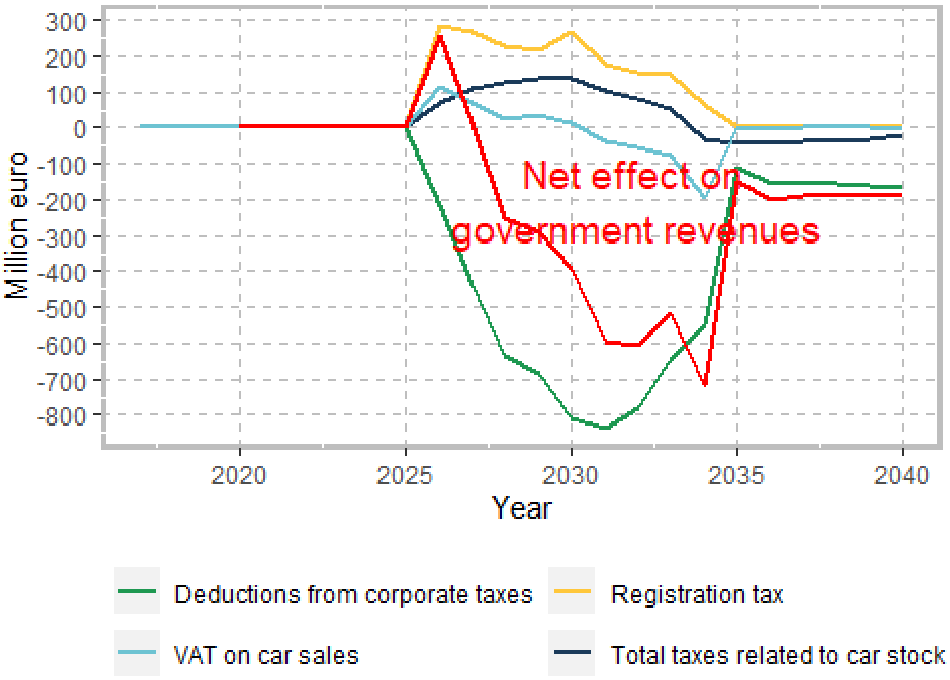
The overall effect of the tax reform in case of a return to pre-2020 sales trends is presented in Graph 38: the tax reform leads to a significant increase in corporate tax revenue: about €1 billion annually in a stable situation (due to the reduced deductibility of electric cars), peaking at about €4 billion between 2030 and 2035.

The results are broadly similar to what we obtain with unchanged categorical variables for the cartypes, although the net effects of the tax reform are somewhat larger.

Graph 38 Net impact on tax revenues with unchanged categorical variables



Graph 39 Net impact on tax revenues: comparison with recalibrated categorical variables



9.2. Higher share of salary cars

We have carried out the analysis above under the assumption that the percentage of cars provided as a benefit in kind (“salary” cars) within the total fleet of company cars is 59%.

Statbel has estimated the total number of “salary” cars using tax records (Belcotax database) on the one hand and social security data on the other. Because these two approaches did not give exactly the same figures, we performed a sensitivity analysis for a share of 68% salary cars.

The only variables that depend directly on this assumption are the taxes associated with the Benefit in Kind and the solidarity contribution.

In Graph 40 we give the impact on taxes that depend on the possession and use of cars. Comparing this with Graph 41, we find that, in the reference scenario, revenue from these taxes is less than 10% higher – exactly what we would expect.

The decrease in revenues[23] due to the tax reform is also slightly larger.

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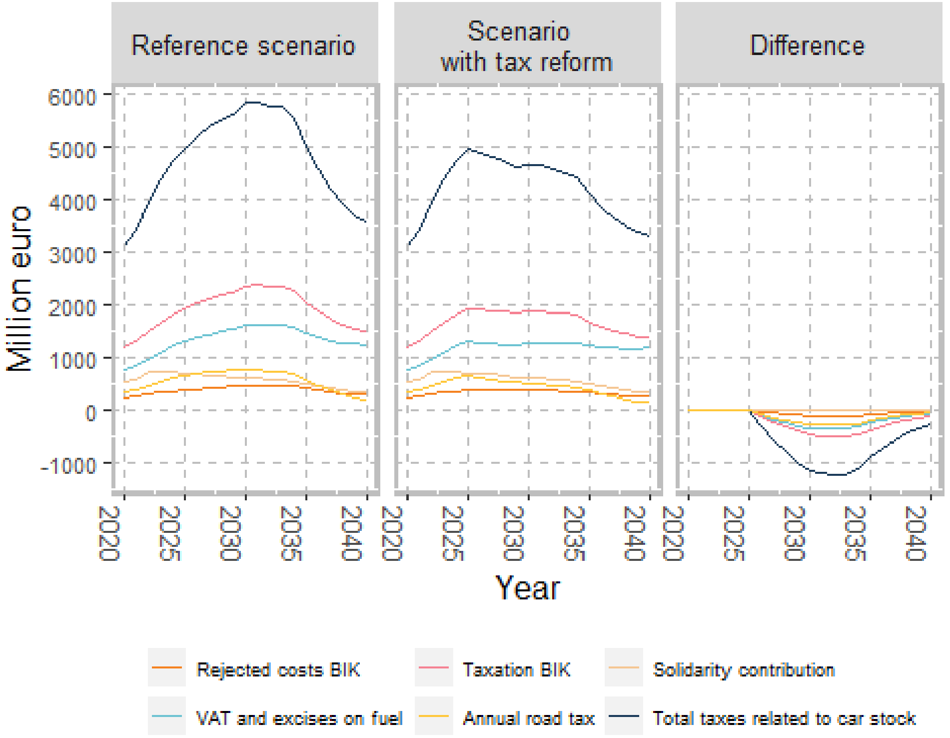
[23] From car ownership and use.

Graph 40 Projection of the tax revenues linked to the ownership and use of company cars with a higher share of salary cars



Graph 41 Projection of the tax revenues linked to the ownership and use of company cars: comparison with the model result with a lower share of salary cars