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The reform of the Flemish registration and annual road taxes

An *ex post* analysis of their impact on the CO_2 emission factors of new cars

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Abstract - The Flemish Region in Belgium reformed its registration tax for passenger cars and its annual road tax in 2012 and 2016 respectively, to reflect a car's CO_2 emissions and Euro pollution class. Moreover, from 2016 to 2020, natural persons and the self-employed could obtain a premium for the purchase of a zero-emission car. Using a difference-in-differences analysis, we find that the reform of the registration tax has caused an accelerated decrease in the CO_2 emission factors of new cars sold in Flanders, compared to other regions. This result holds for privately owned cars as well as company cars. However, the average treatment effect was rather small. The additional effects of the reform of the annual road tax and the zero-emission car premium are even smaller than for the registration tax, and not significant in the case of private cars.

Jel Classification - C54, H23, Q58, R48
Keywords - Causal analysis, difference-in-differences, tax reform, CO_2 emissions, car taxation.

Table of contents

List of tables

List of graphs

Executive summary

In Belgium, the constitutional reform of 1989 transferred the determination of the parameters of the registration tax on car purchases and the annual road tax from the federal state to the regions. However, for more than two decades, the three regions (Brussels Capital, Flanders, Wallonia) maintained the old system where these taxes were determined solely by the car's taxable horsepower.[1]

In 2012, Flanders radically overhauled its registration tax. It now depends on a car's CO_2 emissions and on its Euro standard for pollutant emissions. Moreover, in 2016, Flanders added two correction terms to the annual road tax, to account for a car's Euro standard and CO_2 emissions. In the same year, the penalty for CO_2 emissions in the calculation method for the registration tax in Flanders was also slightly increased. The Brussels and Walloon Regions maintained the existing system.[2] Finally, from 1 January 2016 to 1 January 2020, private persons and self-employed workers in Flanders could obtain a premium for the purchase of zero-emission cars (battery electric cars or fuel cell cars). The value of the premium ranged from 750 EUR to 4000 EUR, depending on the list price of the car.

We thus have a natural experiment with Flanders as a treatment group and the two other regions as control groups that will allow us to test whether the Flemish tax reforms and premium caused a change in the environmental performance of cars. For instance, if the CO_2 emissions of the car fleet are the variable of interest, we can calculate the difference between the CO_2 emissions before and after the tax reform in Flanders and in the rest of Belgium (henceforth ROB), and then calculate the difference between these two differences. If CO_2 emissions in Flanders and in the ROB would have followed a similar path in the absence of the tax reform (the parallel trends assumption), then this "difference-in-differences" (DiD) estimate measures the causal impact of the tax reform on CO_2 emissions in Flanders.

In this paper, we test these hypotheses, using the Belgian national car registry (DIV) to identify all individual purchases of new cars over the period 2007-2019. The records of the DIV contain all the information that is needed to calculate the registration tax and the road tax due (region where the car is registered, whether the purchaser is a private person or a company, CO_2 emissions according to the test cycle, fuel, Euro class, engine size, taxable horsepower).

Both in the case of private cars and company cars, we observe a clear decreasing trend before 2016 and a slight increase in CO_2 emission factors after 2016, both in Flanders and outside . This decrease is observed for both diesel and gasoline cars.

The decrease is larger for company cars, which may be due to two factors in their fiscal treatment. First, since 2007, the deductibility of car related costs in corporate taxation depends on the car's CO_2 emissions, and the parameters have gradually become more stringent through time. Second, when company cars are made available to employees for private purposes, this benefit in kind used to be taxed according to the taxable horsepower of the car. Since January 2012, the taxation of the benefit in kind depends on a car's catalogue value and its CO_2 emissions.

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1 For cars with an internal combustion engine, the taxable horsepower is determined by the engine size at the rate of 1 tax horsepower for every 200 cm3.

2 The Walloon Region has modified its registration tax in 2023. This reform falls outside the time scope of the current paper.

Average CO_2 emissions per km of new passenger cars in Flanders have stayed higher than in the ROB over that period, even if the difference between the two somewhat narrowed after 2011. The key question addressed in this paper is precisely whether this decrease in the gap between Flanders and the ROB has been "caused" by the Flemish tax reform.

Our econometric analysis shows that, over the period 2012-2015, the reform of the registration tax has indeed *caused* an accelerated decrease in the CO_2 emission factors of new cars sold in Flanders, compared to other regions. This result holds for privately owned cars as well as for company cars. However, this additional effect is rather small compared to the overall time trend. There are two factors that help us understand why the overall impact was relatively modest: (a) even though the Flemish reform involved a completely different approach to calculating the registration tax, the parameters determining the tax are positively correlated with the parameters determining the registration tax in the ROB (b) the registration tax is really small compared to the purchase price of new cars.

The additional effect of the reform of the annual road tax and of the introduction of the premium for zero-emission cars is even smaller than for the registration tax, and not even significant in the case of private cars. Again, this outcome is straightforward to understand if one considers the following elements: (a) The reform of the registration tax in 2012 had already created incentives for an accelerated reduction in CO_2 emission factors in Flanders, both for private and for company cars. (b) Even after the reform, the correlation between the annual road taxes in Flanders and the annual road taxes in the ROB remained very high.

Synthèse

Lors de la réforme constitutionnelle de 1989, les compétentes en matière de taxes de circulation et de mise en circulation, notamment la définition de leurs paramètres, ont été transférées de l'État fédéral aux régions. Cependant, pendant plus de deux décennies, les trois régions (Bruxelles-Capitale, Flandre, Wallonie) ont maintenu l'ancien système selon lequel ces taxes étaient déterminées uniquement en fonction des chevaux fiscaux[3] du véhicule.

En 2012, la Flandre a réformé en profondeur sa taxe de mise en circulation (TMC). Elle dépend désormais des émissions de CO_2 du véhicule et de sa classe d'émission Euro. De plus, en 2016, la Flandre a ajouté deux termes correctifs à la taxe annuelle de circulation afin de tenir compte de la norme Euro et des émissions de CO_2 d'une voiture. Cette même année, elle a également légèrement majoré la surtaxe pour les émissions de CO_2 dans le calcul de la TMC. En revanche, Bruxelles-Capitale et la Wallonie ont maintenu le système existant[4]. Enfin, du 1er janvier 2016 au 1er janvier 2020, les particuliers et les indépendants ont pu bénéficier, en Flandre, d'une prime à l'achat de voitures sans émissions (voitures électriques à batterie ou voitures à pile à combustible). La valeur de la prime variait de 750 à 4 000 euros, en fonction du prix catalogue de la voiture.

Ces divergences de politiques nous procurent une expérience naturelle avec la Flandre comme groupe de traitement et les deux autres régions comme groupes de contrôle. Cela nous permet d'examiner si les réformes fiscales et les incitants flamands ont entraîné un changement dans les performances environnementales des voitures particulières. Par exemple, si les émissions de CO_2 du parc automobile sont la variable étudiée, nous pouvons calculer la différence entre les émissions de CO_2 avant et après la réforme fiscale en Flandre et dans le reste de la Belgique (ci-après RdlB), puis calculer la différence entre ces deux différences. Dans l'hypothèse où les émissions de CO_2 en Flandre et dans le reste de la Belgique auraient suivi une trajectoire similaire sans la réforme fiscale (hypothèse de tendances parallèles), cette estimation de la différence dans les différences (DiD) mesure l'impact causal de la réforme fiscale sur les émissions de CO_2 en Flandre.

Nous testons ces hypothèses en utilisant les données de la Direction pour l'Immatriculation des Véhicules (DIV) pour identifier tous les achats individuels de voitures particulières neuves sur la période 2007-2019. La base de données de la DIV contient toutes les informations nécessaires au calcul de la TMC et de la taxe annuelle de circulation (région du propriétaire, personne physique ou morale, émissions de CO_2 selon le cycle d'essai, carburant, classe Euro, cylindrée, puissance imposable).

Tant pour les voitures privées que pour les voitures de société, nous observons une nette tendance à la baisse avant 2016 et une légère augmentation des facteurs d'émission de CO_2 après 2016, tant en Flandre qu'à l'extérieur de la Flandre. Cette baisse est observée tant pour les voitures diesel que pour les voitures à essence.

[3] Pour les voitures à moteur thermique, la puissance fiscale est déterminée par la cylindrée du moteur, à raison de 1 CV fiscal pour 200 cm^3.

[4] La Région wallonne a modifié sa taxe annuelle de circulation en 2023. Cette réforme dépasse le cadre du présent document.

La baisse est plus importante pour les voitures de société, ce qui peut s'expliquer par deux facteurs liés à leur traitement fiscal. Premièrement, depuis 2007, la déductibilité des frais de voiture dans l'impôt des sociétés dépend des émissions de CO_2 de la voiture, et les critères sont devenus progressivement plus stricts au fil du temps. Deuxièmement, lorsque des voitures de société sont mises à la disposition des employés à des fins privées, cet avantage en nature était auparavant taxé en fonction de la puissance fiscale de la voiture. Depuis janvier 2012, l'imposition de l'avantage en nature dépend de la valeur catalogue et des émissions de CO_2 de la voiture.

Les émissions moyennes de CO_2 par km des voitures particulières neuves en Flandre sont restées plus élevées que dans le RdlB au cours de cette période, même si l'écart entre les deux s'est légèrement réduit après 2011. La principale question abordée dans ce document est précisément de savoir si cette diminution de l'écart entre la Flandre et le RdlB a été " causée " par la réforme fiscale flamande.

Notre analyse économétrique montre qu'au cours de la période 2012-2015, la réforme de la TMC a effectivement accéléré la diminution des facteurs d'émission de CO_2 des voitures nouvellement vendues en Flandre par rapport aux autres régions. Ce résultat s'applique aussi bien aux voitures privées qu'aux voitures de société. Toutefois, cet effet supplémentaire est plutôt faible par rapport à la tendance générale en Belgique. Deux facteurs nous aident à comprendre pourquoi l'impact global a été relativement modeste : (a) bien que la réforme flamande ait complètement renouvelé l'approche de calcul de la TMC, les paramètres déterminant la taxe sont positivement corrélés avec ceux de la TMC dans le RdlB (b) la TMC est très basse par rapport au prix d'achat des voitures neuves.

L'effet supplémentaire de la réforme de la taxe annuelle de circulation et de l'introduction de la prime pour les voitures à émissions nulles est encore plus faible que pour la TMC, et n'est même pas significatif dans le cas des voitures particulières. De nouveau, ce résultat est facile à comprendre si l'on considère les éléments suivants : (a) La réforme de la TMC de 2012 avait déjà créé des incitants pour une réduction accélérée des facteurs d'émission de CO_2 en Flandre, tant pour les voitures particulières que pour les voitures de société. (b) Même après la réforme, la corrélation entre la taxe annuelle de circulation en Flandre et la taxe annuelle de circulation dans le RdlB est restée très élevée.

1. Introduction

In Belgium, the constitutional reform of 1989 transferred the determination of the parameters of the registration tax on car purchases and the annual road tax from the federal state to the regions. However, for more than two decades, the three regions (Brussels Capital Region, Flanders, Wallonia) maintained the old system where these taxes were determined solely as a function of a car's taxable horsepower.

In 2012, Flanders radically overhauled its registration tax. It now depends on a car's CO_2 emission and on its Euro standard for pollutant emissions. Moreover, in 2016, Flanders added two correction terms to the annual road tax, to account for a car's Euro standard and CO_2 emissions. In the same year, the penalty for CO_2 emissions in the calculation method for the registration tax in Flanders was also slightly increased. The Brussels and Walloon Regions maintained the existing system.[5] Finally, from 1 January 2016 to 1 January 2020, private persons and self-employed workers in Flanders could obtain a premium for the purchase of zero-emission cars (battery electric cars or fuel cell cars)[6]. The value of the premium ranged from 750 EUR to 4000 EUR, depending on the list price of the car.

We thus have a natural experiment with Flanders as a treatment group and the two other regions as control groups that will allow us to test whether the Flemish tax reforms and premium caused a change in the environmental performance of cars. For instance, if the CO_2 emissions of the car fleet are the variable of interest, we can calculate the difference between the CO_2 emissions before and after the tax reform in Flanders and in the rest of Belgium (henceforth ROB), and then calculate the difference between these two differences. If CO_2 emissions in Flanders and in the ROB would have followed a similar path in the absence of the tax reform (the parallel trends assumption), then this "difference-in-differences" (DiD) estimate measures the causal impact of the tax reform on CO_2 emissions in Flanders.

In this paper, we test these hypotheses, using the Belgian national car registry (DIV) to identify all individual purchases of new cars over the period 2007-2019. The records of the DIV contain all the information that is needed to calculate the registration tax and the road tax due (region where the car is registered, whether the purchaser is a private person or a company, CO_2 emissions according to the test cycle, fuel, Euro class, engine size, taxable horsepower).

The paper is structured as follows. First, we provide an overview of the literature exploiting the regional variation in tax regimes or energy prices within a country to measure the impact of these taxes and prices on the environmental performance of the transport sector using DiD. We give a short overview of these applications. Second, we discuss how the registration tax and the annual road tax are calculated in each region, and describe how the average values of these taxes have evolved over time. Third, we narrow down the scope of the analysis to the CO_2 emissions of new passenger cars. Fourth, we describe the evolution over time of two key variables: the average CO_2 emission factors of new passenger cars for Flanders and the rest of Belgium on the one hand, and the shares of different powertrains in the sales

5 The Walloon Region has modified its registration tax in 2023. As the reform will only take effect as from 2025, it falls outside the time scope of the current paper.

6 A premium was recently reintroduced in Flanders for the purchase of zero-emission vehicles, but this measure falls outside the timeframe of this study – see https://www.vlaanderen.be/premie-voor-aankoop-van-een-zero-emissievoertuig

of new passenger cars on the other hand. Fifth, we conduct the actual difference-in-differences analysis for the registration tax and the annual road tax. Finally, we offer some concluding thoughts.

2. Literature review

Mannberg et al. (2014) were able to estimate the effect of the Stockholm congestion tax on the probability of purchasing an ethanol car since ethanol cars were exempt from the congestion tax between 2006 and 2009. They estimated a DiD probit model for the period 2004–2008, using a random sample of individuals living in Stockholm, Gothenburg or Malmö, with Gothenburg and Malmö as control groups.

Alberini et al. (2018) exploited the variation between Swiss cantons in the annual registration fees to measure the impact of these fees on the lifetime of existing cars.

Ciccone (2018) analysed the reform of the vehicle registration tax in Norway, and identified the impact of the new tax structure on three main dimensions: (i) the average CO_2 emissions intensity of new registered vehicles, (ii) the relative change in sales between low and high CO_2-intensive cars and (iii) the market share of diesel cars. Given that the tax reform was applied to all vehicles across Norway, Ciccone compensated for the lack of control group by employing previous observations in time that were comparable to the primary observations of interest. A similar strategy has been used by Tesemma (2023) to analyse the impact of a vehicle tax reform in Ethiopia.

Pretis (2022) evaluated the carbon tax that was introduced in British Columbia (Canada) in 2008. This tax was levied on the consumption of fossil fuels for transport, residential heating and electricity. The introduction of the British Columbia carbon tax was detected as a structural break in transportation CO_2 emissions. First, Pretis performed a conventional DiD where he imposed the intervention (the introduction of the CO_2 tax) and the timing (200) on the model. Next, Pretis introduced a break-detection approach using machine learning in fixed effects panel estimation that allows for the detection of treated units and treatment dates without prior knowledge of their occurrence. Intuitively, the purpose of this approach is to find which - previously unknown — interventions were statistically significant and when they occurred.

Mauritzen (2023) used price differences between geographical zones within Norway to estimate the effect of electricity prices on the market share of electric cars.

Morton and Yasir (2023) measured the impact of the London congestion charge on private car registrations outside of the congestion charge boundary, exploiting that areas located within the charging zone enjoyed a steep resident discount on the congestion charge.

It is also possible to use international variation in policies to estimate causal impacts. For instance, Li et al. (2010) evaluated the impact of a “Cash-for-Clunkers” scheme in the US, using Canada as the control group.

3. Taxes on the purchase and ownership of passenger cars

The registration tax is applied to passenger cars at each purchase, including on the second-hand market. The annual road tax is levied on all motor vehicles and their trailers. Some cars are exempted from these taxes because of their specific purpose (for instance, emergency vehicles).

In Belgium, setting the parameters of the registration tax and 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. Until now, the fiscal regime for leased cars follows the regime in the Brussels region.

In what follows, we describe the evolution of these taxes between 2007[7] and 2020.

3.1. The registration tax

In the Brussels and Walloon Regions, the tax is determined by a car's taxable horsepower and power expressed in kW. Table 1 represents the tariffs for newly purchased cars – these tariffs are not indexed. When there is a conflict between the amount based on the taxable horsepower (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. These values have remained constant.

Table 1 Registration tax on new cars in the Brussels and Walloon Region

HP	kW	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

Since 2009, 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).

From 2009 until 2013, the Walloon region also applied an "ecobonus" to cars that emitted less than 80 gr of CO_2 per km.

The Flemish Region followed the same calculation method as the two other regions until 1 March 2012, and then moved to a calculation method that takes into account CO_2 emissions and the Euro standard of the car. Until 2021, the following formula applied :

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

where:

[7] The method that is currently used for the calculation of the annual road tax in Brussels and in the Walloon Region was first introduced in 2007, so this seems a natural starting point.

- D = 250 until 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) = 4.5 per gr of CO_2 per km in 2013 (increases with 4.5 per year);
- LC: correction for age - LC = 100 for new cars and decreases linearly by 10 points per year until the minimum value of 10 is reached;
- c: correction term for air quality, that depends on the fuel and Euro norm for the car – see Table 2 and Table 3.

Table 2 Registration tax air quality correction term for diesel cars

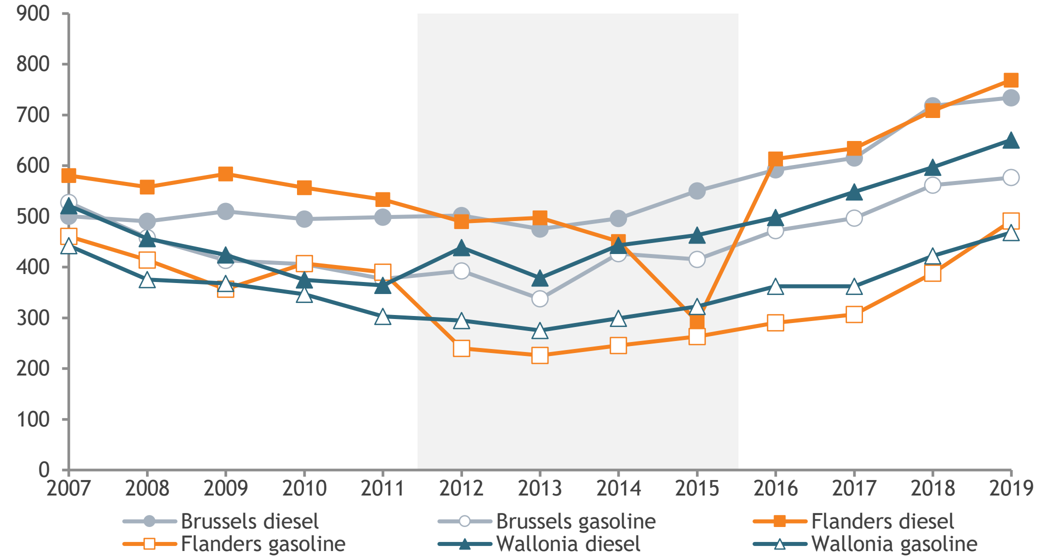
EuroCl	1 July 2012 to 30 June 2013	1 July 2013 to 30 June 2014	1 July 2014 to 30 June 2015	1 July 2015 to 30 June 2016	1 July 2016 to 30 June 2017	1 July 2017 to 30 June 2018	1 July 2018 to 30 June 2019
Euro 0	2190.18	2215.96	2223.94	2863.15	2926.14	2980.54	3034.65
Euro 1	642.56	650.13	652.47	840.00	858.48	874.44	890.32
Euro 2	466.11	471.60	473.30	493.36	636.27	648.10	659.86
Euro 3	367.27	371.59	372.93	467.06	504.21	513.59	522.91
Euro 4	347.15	351.23	352.49	467.06	477.34	486.21	495.04
Euro 5	341.25	345.26	346.50	459.35	469.34	478.12	486.87
Euro 6	12.59	12.74	12.79	445.07	464.04	472.69	481.27

Table 3 Registration tax air quality correction term for gasoline, LPG- and CNG cars

EuroCl	1 July 2012 to 30 June 2013	1 July 2013 to 30 June 2014	1 July 2014 to 30 June 2015	1 July 2015 to 30 June 2016	1 July 2016 to 30 June 2017	1 July 2017 to 30 June 2018	1 July 2018 to 30 June 2019
Euro 0	871.12	881.37	884.54	1138.78	1163.83	1185.47	1206.99
Euro 1	389.58	394.16	395.58	509.28	520.48	530.16	539.79
Euro 2	116.49	117.87	118.29	152.29	155.64	158.53	161.41
Euro 3	73.08	73.94	74.21	95.53	97.63	99.45	101.25
Euro 4	17.54	17.75	17.81	22.93	23.43	23.87	24.30
Euro 5	15.77	15.96	16.02	20.61	21.06	21.46	21.84
Euro 6	15.77	15.96	16.02	20.61	21.06	21.46	21.84

In Flanders, there is also a lower bound of 41.61 and an upper bound of 10402 EUR to the registration tax (values for 2013, indexed annually). Electric cars are exempted from the tax. Until 2021, this exemption also applied to cars with CNG engines and plug-in hybrid cars (PHEV) that emit at most 50 gr of CO_2 per km (until 2015, all PHEV were exempted).

Graph 1 Evolution of average registration taxes for new diesel and gasoline cars over the period 2007-2019



Source: Own calculations based on data from the national car registry

Graph 1 represents the sales-weighted average registration tax of new diesel and gasoline cars in the three Belgian regions.

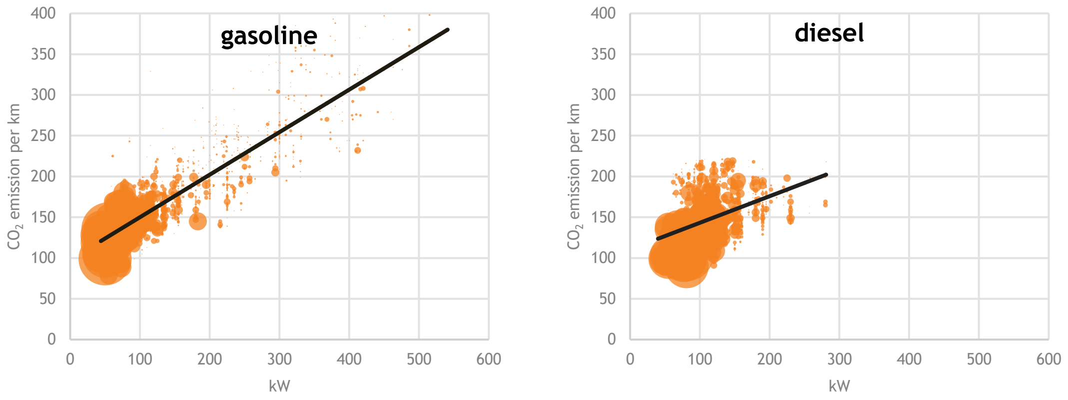
For diesel cars, the tax reform in Flanders had no immediately discernible effect: the average value remained close to the average value in Brussels and above the average value in Wallonia.

The sudden one-off drop in the average value of the registration tax for diesel cars in 2015 is due to differences in timing between changes in the European emission standards and changes in the parameters of the registration tax: all diesel cars first registered after 1 September 2015 had to comply with the Euro 6 standard but the air quality correction term for Euro 6 diesel cars remained very low in 2015 (see Table 2).

In 2016, the denominator in the formula for the registration tax in Flanders was lowered, and the registration tax thus increased for given CO_2 emissions. The average value of the registration tax for diesel cars also increased in the two other regions, reflecting an increase in the maximum power of new passenger cars.

For gasoline cars, the picture is slightly different. Until 2012, the average value in Flanders remained between the average values in Brussels and Wallonia. After the tax reform, average values in Flanders dropped initially by -38.52%, and gradually increased since. Until 2019, they remained below the values in Brussels and Wallonia.

Graph 2 CO_2 emissions versus maximum power in 2012



Source: Own calculations based on data from the national car registry

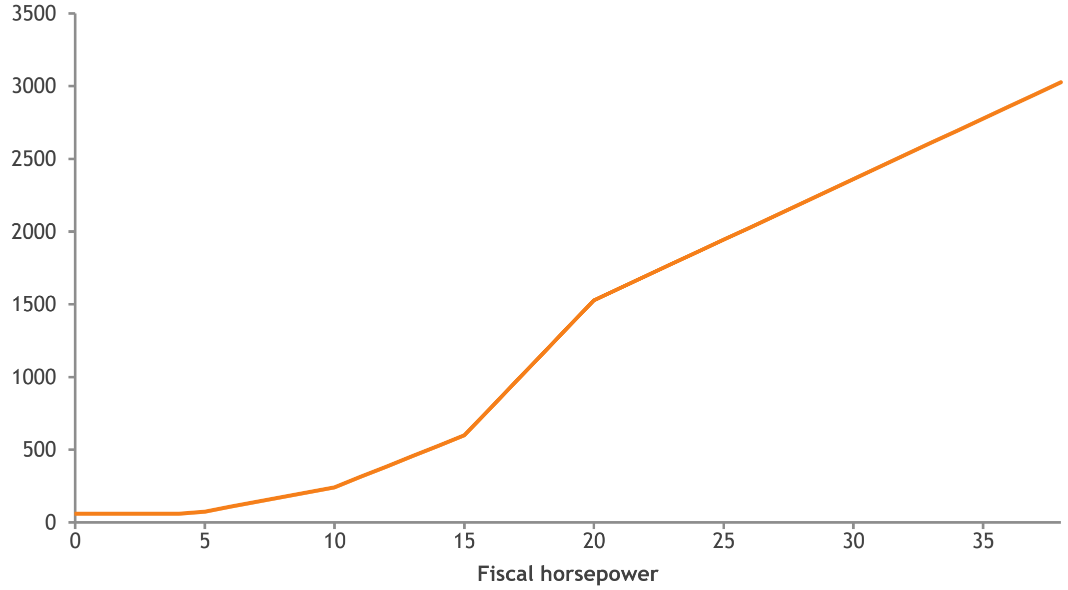
The overall picture that emerges from Graph 1, however, is not one where the reform of the registration tax in Flanders leads to a fundamental change. This is not surprising, if one takes a look at Graph 2, which gives the scatterplot between the determinant of the registration tax in Brussels and Wallonia (the maximum engine power) and one of the key parameters in the calculation of the registration tax in Flanders (CO_2 emissions per km) in the first year after the reform (2012).[8] For gasoline cars, the correlation coefficient between these two variables is 0.75; for diesel cars, it is 0.62. These correlations for individual fuels do not tell us the whole story: following the reform, prospective car buyers can also decide to switch fuels rather than choose cars with lower CO_2 emissions for a given fuel. However, one should keep this in mind when discussing the results of our difference-in-differences analysis.

3.2. The annual road tax

Historically, the tariffs were based on the taxable horsepower (HP) of the car, and the Brussels and Walloon Regions have maintained this system. Graph 3 presents the tariffs that were applicable in those Regions in 2007 as a function of the taxable horsepower. Cars with less than 4 taxable horsepower are subject to the minimum tariff of 59.76 EUR. For each additional HP above 20 HP, 83.28 EUR is added to the tax. These tariffs are indexed annually.

[8] Similar patterns emerge for the other years.

Graph 3 Annual road tax in het Brussels and Walloon Region as a function of horsepower
Euro



Source: Own calculations

The base tariffs in Flanders are very close to the values that apply in Brussels and Wallonia. However, for cars registered after 1 January 2016, a double environmental correction is added to this base tariff in Flanders.

First, there is a correction for the CO_2 emissions: 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. The threshold, the surcharge and the discounts have remained constant over the period 2016-2019.

Second, there is a correction depending on the fuel, the Euro standard and on whether the car has a particle filter – see Table 4. This correction has remained constant over the period 2016-2019.

Table 4 Flanders: correction applied to the annual road tax according to fuel and Euro class

Euronorm	Diesel	Gasoline, LPG and CNG
Euro 0	+50%	+30%
Euro 1	+40%	+10%
Euro 2	+35%	+5%
Euro 3	+30%	+0%
Euro 3 + particle filter	+30%	Not applicable
Euro 4	+25%	-12.5%
Euro 4 + particle 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. Until 2021, this exemption also applied to PHEV cars that emit at the most 50 grams of CO_2 per km and to cars running on natural gas.

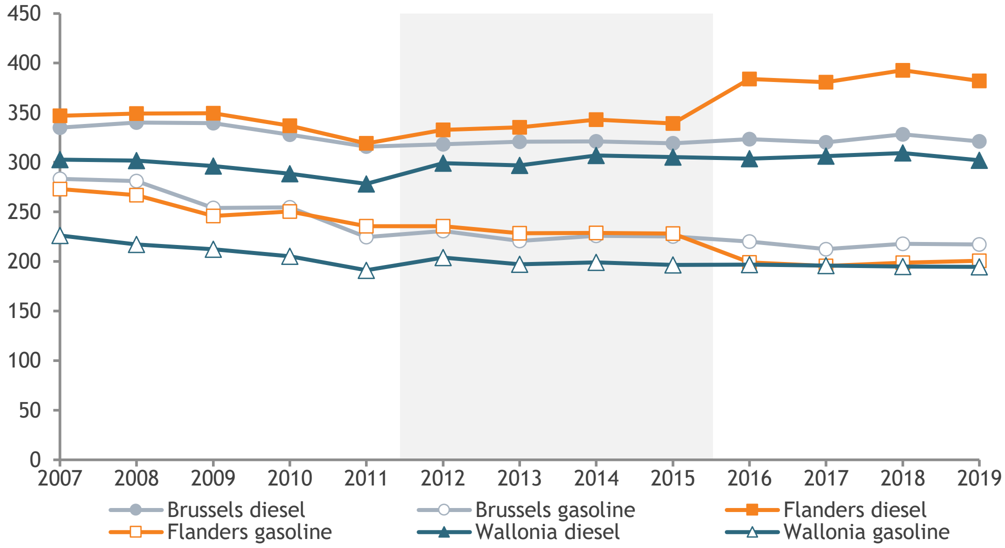
In the three regions, an additional tax is applied to cars that run on LPG.

Table 5 Surtax for LPG cars

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 traffic tax.

Graph 4 Evolution of average road taxes for new diesel and gasoline cars over the 2007-2019 period

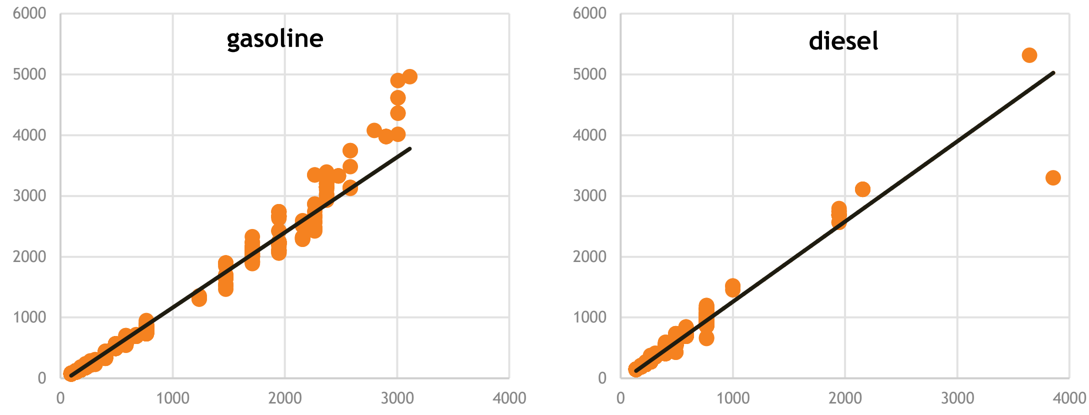


Source: Own calculations based on data from the national car registry

Graph 4 shows the evolution of the average road tax for new gasoline and diesel cars over time in each of the three Regions.

Until the tax reform, the tariffs for the road tax were uniform throughout Belgium, and differences in the mean values were uniquely due to differences in the composition of sales in the three regions. After the 2016 tax reform, the average tariffs for diesel cars in Flanders increased by 13.24%, while those for gasoline cars decreased by -12.67%.

Graph 5 Road taxes in Brussels versus Flanders in 2016



Source: Own calculations based on data from the national car registry

Note that, despite the two correction factors, the overall correlation between the road taxes in Flanders and those in the other regions remains very high - 0.99 in 2016, the first year when the correction terms were added in Flanders.

4. Scope of the analysis

As we have seen above, the new Flemish registration and road taxes depend not just on the CO_2 emissions of the car, but also on its Euro standard (which regulates its emissions of local pollutants). Moreover, the registration tax applies to all sales, including sales on the second-hand market, while the annual road tax covers all cars in stock. These taxes interact with regulatory standards, such as the European emission limits for CO_2 on the one hand and those for local pollutants (the so-called Euro norms) on the other hand.

In this section, we discuss how these elements affect the scope of our analysis.

First, compliance with the most recent Euro norms acts as a binding constraint on the first *registration* of all individual *new* cars. If new cars are usually sold to customers quickly after their first registration[9], the Flemish taxes will have at the most a marginal impact on the Euro standard of *new* registered cars. However, the Euro standard term in the registration class and the annual road tax are higher for diesel cars than for gasoline cars (see Table 2 and Table 3). Therefore, the Euro standard term may affect the market shares of the fuel types – and thus the average emissions of new cars.

However, there exists no such binding constraint for the CO_2 emissions at the level of individual cars: the European limits pertain to the average emissions of the new sales at the *European* level. Therefore, the changes in the Flemish road taxes are expected to affect the CO_2 emissions of *new* cars. Buyers can lower the road tax, either by switching to a powertrain with lower CO_2 emissions, or by buying more fuel-efficient cars for a given powertrain.

Note that the market share of different powertrains will be affected by two opposing forces: the CO_2 correction term is an incentive for buying more fuel-efficient diesel cars, while the Euro standard correction puts diesel cars at a disadvantage. As we can see from Graph 1 and Graph 4, the reform of the registration tax and the annual road tax puts a heavy penalty on diesel cars compared to gasoline cars. However, we would always expect CO_2 emissions for a given powertrain to decrease.

For the time period we consider here, the Belgian car registry contains the CO_2 emissions of all new cars measured by the NEDC test cycle. We thus have a consistent time series to measure the impact of the tax reforms on the CO_2 emissions of new cars. However, for older cars, this information is often missing, and we cannot directly measure the impact on the CO_2 emissions of the existing car stock.

For pollutants[10], the situation is more complex.

Indeed, except for carbon monoxide (CO), the scope of the successive Euro standards has changed over time. For instance, particulate matter (PM) emitted by gasoline cars has only been covered since the application of the Euro5a standard to new cars in 2011. Since 2013, the emission limits for new gasoline and diesel cars were the same. Also, in the case of gasoline cars, in the Euro 1 and Euro 2 standards, it was the sum of hydrocarbons (HC) and nitrogen oxides (NOx) that was covered. From Euro 3 on

9 If a car is initially registered by a garage, there can be a gap between the first registration and the first sale.
10 In what follows, we use the word "pollutants" to refer to emissions that are covered by the Euro standards.

(applicable to new cars since 2001), only NOx emissions were covered. Hence, except for CO, it is not possible to calculate the average emission factors for the *stock* for gasoline cars. Moreover, the emission standards for CO have remained constant since the entry into application of the Euro 4 standards in 2006. Hence, in the absence of consistent time series, it is not possible to estimate the impact of the tax reforms on pollutant emissions of the existing stock.

In summary, it is only for the CO_2 emission factors that we can consistently measure changes through time at the level of individual cars.

Finally, note that the reformed road tax in Flanders only affects cars that have been first registered after 31 December 2015. Therefore, the reform of the annual road tax does not provide incentives for an accelerated scrappage of old cars for the time period we consider here.[11]

[11] Note that Alberini et al. 2018 do estimate the impact of tax reforms on the lifetime of existing cars as consumers change the Euro class of their car by replacing it with a younger model.

5. CO_2 emissions of new passenger cars from 2007 to 2019 included

The average emissions of all new cars follow from (a) the average emissions of each fuel type (b) the market shares of each fuel type. We now address both in turn.

First, in Graph 6, we show the evolution through time of the average CO_2 emissions per km of new diesel and gasoline cars in Flanders and the ROB from 2007 until 2019 – the year before the new, more stringent EU standards for the CO_2 emissions of new passenger cars entered into force.

Both in the case of private cars and in the case of company cars, we observe a clear decreasing trend before 2016 and a slight increase in CO_2 emission factors after 2016, both in Flanders and outside Flanders[12]. This decrease is observed for both diesel and gasoline cars.

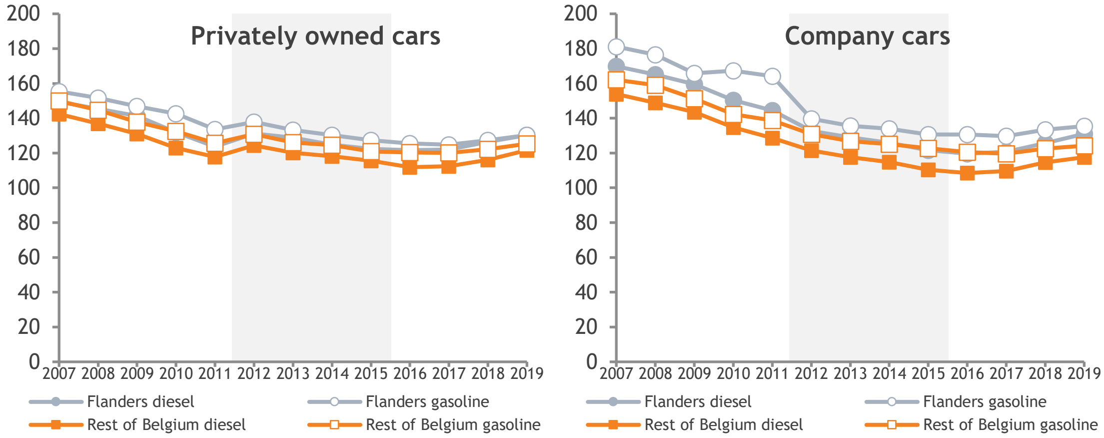
In the case of private cars, we also observe a more pronounced decrease in the average CO_2 emissions of new cars in 2011, followed by a rebound in 2012. This is due to the abolition in early 2012 of the federal "eco-premium" of 15% on the purchase price of new cars with CO_2 emissions of 105 gram per km or less. In the anticipation of this change, in 2011, there was an important increase in the sales of cars that were eligible for this premium.

The decrease is larger for company cars, which may be due to two factors in their fiscal treatment. First, since 2007, the deductibility of car related costs in corporate taxation depends on the car's CO_2 emissions, and the parameters have gradually become more stringent through time. Second, when company cars are made available to employees for private purposes, this benefit in kind used to be taxed according to the taxable horsepower of the car. Since January 2012, the taxation of the benefit in kind depends on a car's catalogue value and its CO_2 emissions.

Average CO_2 emissions per km of new passenger cars in Flanders have stayed higher than in the ROB over that period, even if the difference between the two somewhat narrowed after 2011 – the key question addressed in this paper is precisely whether this decrease in the gap between Flanders and the ROB has been "caused" by the Flemish tax reform.

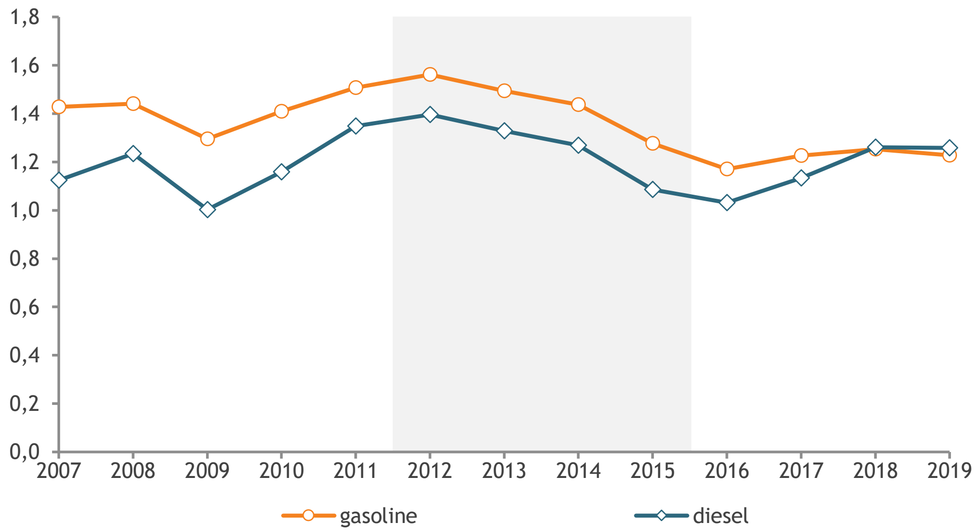
[12] Note that, in the case of company cars, "rest of the country" includes lease cars registered in Flanders, that are not subject to the same registration and road taxes as privately owned cars and cars owned by other legal entities.

Graph 6 Evolution of average CO_2 emissions new cars per tax regime and fuel type over the period 2007-2019
g/km



Source: Own calculations based on data from the national car registry

Graph 7 Evolution of gasoline and diesel prices (all taxes included) over the period 2007-2019
Euro/liter

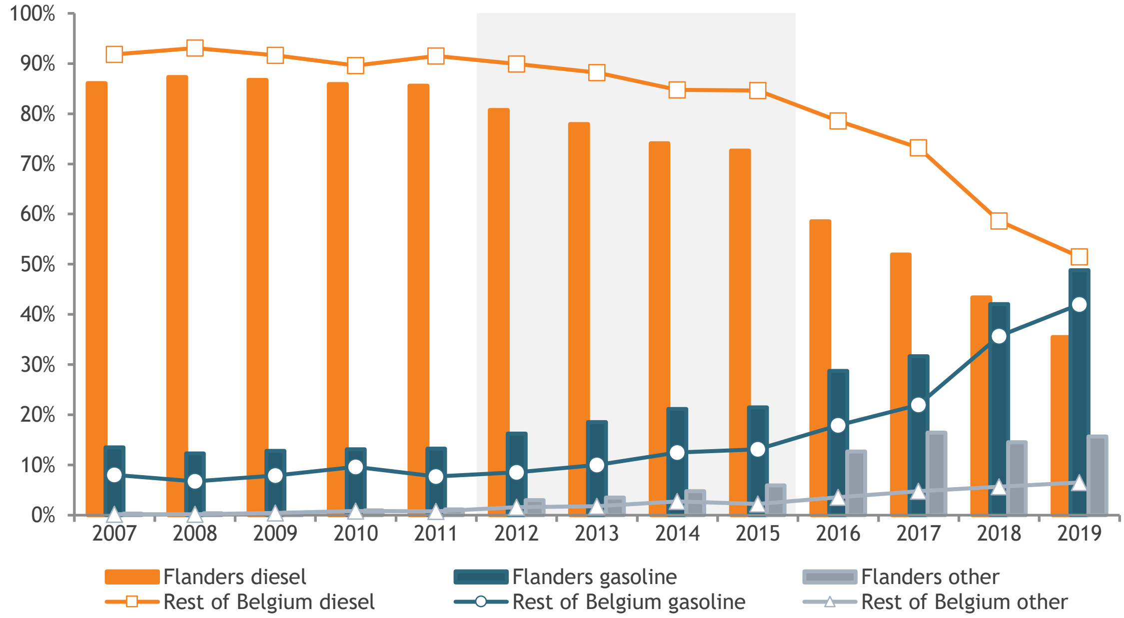


Source: Own calculations based on https://www.energiafed.be

Between 2009 and 2013, the general tendency was for fuel prices to increase (see Graph 7), which may explain part of the decrease in CO_2 emissions per km. Also, European Union Directive No 443/2009 set a 2015 target of 130 g/km for the fleet average for new passenger cars. Some may argue that this explains the decrease from 2009 to 2015. However, one must keep in mind that the EU standards are EU-wide, and that there is no obligation to meet them at the level of individual member states. Also, it is difficult to understand why any anticipation effects would have played in the years *before* 2015: quite on the contrary, one would expect car manufacturers to get rid of their gas guzzlers before the constraints set it. However, this does not explain why CO_2 emission factors started increasing again after 2016. The relation between the EU CO_2 standards and the CO_2 emissions factors of new cars in Belgium thus appears tenuous at best.

Graph 8 Evolution of the market shares of different powertrains in the sales of new cars over the period 2007-2019

%



Source: Own calculations based on data from the national car registry

Second, we need to look at the shares of different powertrains.

The graphical analysis in Graph 8 clearly reveals that the move away from diesel to gasoline had already begun before 2016, in all regions of Belgium and for all ownership types. The decrease in the market share of diesel cars is especially spectacular for private cars.

For privately owned cars in Flanders, the market share for gasoline cars was already higher than for diesel cars in 2013. In the other two regions, however, the market share for gasoline cars only surpassed that of diesel cars in 2015.

In the case of company cars, the market share for diesel cars remained higher than that of gasoline cars until 2018 in Flanders and until 2019 in the ROB.

All other things being equal, a higher share of gasoline cars should result in higher average CO_2 emissions per km.

Finally, starting in 2015, the market shares of alternative fuels (electric cars, hybrid cars, PHEV) are no longer negligible, especially in the case of company cars.

In summary, the overall decrease in CO_2 emissions per km of new passenger cars results from two opposing forces: the increasing share of gasoline cars compared to diesel cars (which should lead to higher CO_2 emissions) versus the decreasing CO_2 emissions per km for all powertrains.

6. Statistical analysis CO_2 emissions of new cars

In what follows, we will present separate models for privately owned cars and company cars. There are indeed several reasons why the behavioural reactions to the tax are likely to depend on the ownership type. First, company cars are deductible in corporate taxation, while the benefit-in-kind of company cars used for private purposes is also subject to income taxation. The VAT on company cars is also (partially) deductible. These taxes affect the choices between different car models. Second, the annual mileage of company cars is higher, but their first owner typically sells them on the second-hand market after two to four years. These two elements affect the total cost of ownership, and thus also the choices of buyers. Third, one would expect fleet managers to give a higher weight to financial criteria than private households.

6.1. Difference-in-differences model for the registration tax

We estimate the following model for the reform of the registration tax:

$$CO_{2,i,t} = \alpha_0 + \alpha_1 \,.\, \text{RgFl} + \alpha_2 \,.\, \overline{Y} + \sum_{t=2008}^{2015} \alpha_{3,Yr} \,.\, \text{I}\,(\text{Yr}\,) + \sum_{t=2012}^{2015} \alpha_{4,Yr} \,.\, \text{I}\,(\text{Yr}\,) \,.\, \text{RgFl}$$

Equation 1

where $CO_{2,i,t}$ are the emissions of car model i in year t according to the testcycle, I (Yr) = 1 if t = Yr and 0 otherwise and RgFl = 1 if the car is registered in Flanders and 0 otherwise.

The intercept α_0 corresponds to the estimated average CO_2 emission factors in 2007 in the ROB, and $\alpha_0 + \alpha_1 \; RgFl$ to estimated average CO_2 emission factors in 2007 in Flanders.

α_2 measures the impact of income. In the absence of household data, $\overline{Y}$ measures the average household income in the municipality where the car was registered. Note that we only estimate α_2 for private cars: for company cars, the average household income in the municipality where the company is registered is unlikely to affect the purchase decisions of the fleet managers.

The $\alpha_{3,Yr}$ coefficients measure the time trends that are common to all regions in Belgium for all years ranging from 2008 to 2016. They summarize the impact of the variables that change through time and affect the CO_2 emission factors of cars, but are not measured.

For each year from 2012 to 2016, the $\alpha_{4,Yr}$ coefficients measure the average difference in CO_2 emission factors in Flanders compared to the Belgian average. Under the hypothesis of parallel trends, the $\alpha_{4,Yr}$ coefficients measure the causal impact of the reform of the Flemish registration tax (which entered into application in 2012) on the CO_2 emission factors of new cars in Flanders. In other words, these coefficients measure the treatment effects. If the Flemish reform of the registration tax (which took effect in 2012) has caused a decrease in CO_2 emissions compared to a no-reform counterfactual, we would expect $\alpha_{4,Yr} < 0$.

In order to insulate our estimates from the effects of the changes in the Flemish road tax and from the introduction of the premium for zero emissions cars (both of which entered into application in 2016), we limit our post-2011 observations to the end of 2015.

Following the terminology in Bilinski and Hatfield (2019) (and for reasons to be explained below), we call this the reduced model.

Table 6 DiD Model for the registration tax

	Private cars: reduced model	Company cars: reduced model	Private cars: expanded model	Company cars: expanded model
α_0	139.88 ***	154.53 ***	140.05 ***	154.61 ***
	(0.41)	(0.20)	(0.43)	(0.22)
α_1	8.25 ***	16.94 ***	6.87 ***	15.75 ***
	(0.15)	(0.20)	(0.91)	(1.25)
α_2	0.27 ***		0.27 ***	
	(0.03)		(0.03)	
$\alpha_{3,2008}$	-4.94 ***	-4.95 ***	-5.02 ***	-4.99 ***
	(0.23)	(0.27)	(0.23)	(0.28)
$\alpha_{3,2009}$	-10.03 ***	-10.66 ***	-10.19 ***	-10.73 ***
	(0.23)	(0.29)	(0.25)	(0.30)
$\alpha_{3,2010}$	-17.96 ***	-19.24 ***	-18.20 ***	-19.35 ***
	(0.22)	(0.28)	(0.27)	(0.31)
$\alpha_{3,2011}$	-25.14 ***	-25.25 ***	-25.46 ***	-25.40 ***
	(0.22)	(0.28)	(0.31)	(0.31)
$\alpha_{3,2012}$	-17.52 ***	-32.83 ***	-17.69 ***	-32.90 ***
	(0.31)	(0.31)	(0.33)	(0.32)
$\alpha_{3,2013}$	-21.87 ***	-36.59 ***	-22.04 ***	-36.67 ***
	(0.32)	(0.31)	(0.33)	(0.32)
$\alpha_{3,2014}$	-23.74 ***	-39.43 ***	-23.90 ***	-39.50 ***
	(0.32)	(0.31)	(0.34)	(0.32)
$\alpha_{3,2015}$	-26.58 ***	-43.32 ***	-26.74 ***	-43.39 ***
	(0.33)	(0.31)	(0.35)	(0.32)
$\alpha_{4,2012}$	-1.34 ***	-5.83 ***	-1.78 ***	-6.23 ***
	(0.37)	(0.48)	(0.47)	(0.64)
$\alpha_{4,2013}$	-0.48	-6.01 ***	-1.07 *	-6.54 ***
	(0.37)	(0.49)	(0.53)	(0.74)
$\alpha_{4,2014}$	-2.28 ***	-6.87 ***	-3.02 ***	-7.53 ***
	(0.37)	(0.48)	(0.61)	(0.84)
$\alpha_{4,2015}$	-2.02 ***	-8.05 ***	-2.91 ***	-8.84 ***
	(0.39)	(0.47)	(0.70)	(0.95)
α_5			0.15	0.13
			(0.10)	(0.14)
N	343526	212003	343526	212003
R2	0.09	0.24	0.09	0.24

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

The reduced model estimates can be found in the two left columns of Table 6.

All estimated coefficients are highly significant.

The sign of α_1 implies that, in 2007, average CO_2 emissions per km were higher in Flanders than in the ROB, both for private cars and company cars, even after controlling for income in the case of private cars. As expected, average CO_2 emissions per km for privately owned cars are higher in municipalities with higher average household incomes ($\alpha_2 > 0$).

$\alpha_{3,Yr} < 0$ for $Yr = 2008, \ldots, 2015$, both for privately owned cars and company cars. This confirms the generally downward trend of CO_2 emission factors since 2007.

$\alpha_{4,Yr} < 0$ for $Yr = 2012, \ldots, 2015$: in each year after the reform of the registration tax in Flanders, CO_2 emissions factors of new cars decreased more quickly in Flanders than in the ROB.

Instead of comparing the individual values for $\alpha_{3,Yr}$ and $\alpha_{4,Yr}$, it can be enlightening to look at the average values after the change in the Flemish registration tax entered into application.

From 2012 to 2016, the average value for the time-dummies in the reduced model is $\alpha_{3,R,PC} = \frac{1}{4}\sum_{t=2012}^{2015} \alpha_{3,Yr}$ = -22.43 for private cars and $\alpha_{3,R,CC}$ = -38.04 for company cars. The average treatment effect in the reduced model is $\alpha_{4,R,PC} = \frac{1}{4}\sum_{t=2012}^{2015} \alpha_{4,Yr}$ = -1.53 for private cars and $\alpha_{4,R,CC}$ = -6.69 for company cars. Note that $\frac{\alpha_{4,R,PC}}{\alpha_{3,R,PC}}$ = 6.81% for private cars and $\frac{\alpha_{4,R,CC}}{\alpha_{3,R,CC}}$ = 17.59% for company cars.

However, we can only conclude that the reform of the registration tax has *caused* this accelerated decrease if the difference in CO_2 emission factors between Flanders and the ROB would have remained constant in the absence of the reform of the registration tax. Or, in other words, we can only take the changes in CO_2 emission factors in the ROB after the reform of the registration tax as the relevant counterfactual for the changes in CO_2 emission factors in Flanders after the reform of the registration tax if CO_2 emissions of new passenger cars in Flanders follows parallel trends with those in the ROB. If parallel trends hold, we can assume that common exogenous shocks have had the same impact in Flanders as in the ROB.

However, instead of testing for parallel trends, we follow the approach proposed by Bilinski and Hatfield (2019). We: (a) estimate baseline estimates from a model with a more complex difference between treatment and comparison group than parallel (the "expanded model") (b) compare the treatment effect from the expanded model with the treatment effect estimated from a model that constraints trend differences to be simpler (the "reduced model"). In the current analysis, we have constrained the time trends before the reform of the registration tax to be equal in the reduced model.

Bilinski and Hatfield (2019) argue that the expanded model should be the base model, as it would introduce a bias in the model estimates to just assume that the treatment and the control group follow the same pre-reform trends. However, as Bilinski and Hatfield (2019) point out, the primary unit of interest is not whether the hypothesis of parallel trends is violated, but the impact of the violation of this hypothesis on the treatment effects. Therefore, we calculate the difference in average treatment effects between the two models.

A drawback of this approach is that, if parallel trends hold, adding a trend difference between Flanders and the ROB increases the standard error of the treatment effects.

For the expanded model, we estimate the following equation:

$$\mathrm{CO}_{2,i,t} = \alpha_0 + \alpha_1 \,.\, \mathrm{RgFl} + \alpha_2 \,.\, \overline{Y} + \sum_{t=2008}^{2015} \alpha_{3,Yr} \,.\, I(\mathrm{Yr}) + \sum_{t=2012}^{2015} \alpha_{4,Yr} \,.\, I(\mathrm{Yr}) \,.\, \mathrm{RgFl} + \alpha_5 \,.\, \mathrm{T} \,.\, \mathrm{RgFl}$$

Equation 2

which is identical to Equation 1, except that we have added $\alpha_5 . \mathrm{T}. \mathrm{RgFl}$, where T is the linear time trend.

If the parallel trends assumption holds, we would expect that α_5 is not significantly different from zero[13] – and this turns out to indeed be the case, both for private cars and for company cars.

The estimates for the expanded model estimates can be found in the two right columns of Table 6. The estimates for α_0, α_1, α_2 (in the case of private cars), $\alpha_{3,Yr}$ and $\alpha_{4,Yr}$ are close to the values we found for the reduced model - which is consistent with α_5 not being statistically significant.

In other words, even after adding a specific linear time trend for Flanders, we maintain our conclusion that after the reform of the registration tax in Flanders, CO_2 emissions factors of new cars decreased more quickly in Flanders than in the ROB.

Just as in the reduced model, we find that $\alpha_{3,Yr} < 0$ for $Yr = 2008, \dots, 2015$ and $\alpha_{4,Yr} < 0$ for $Yr = 2012, \dots, 2015$.

From 2012 to 2016, the average value for the time-dummies in the extended model is $\alpha_{3,E,PC} = \frac{1}{4}\sum_{t=2012}^{2015} \alpha_{3,Yr}$ = -22.59 for private cars and $\alpha_{3,E,CC}$ = -38.12 for company cars. The average treatment effect in the extended model is $\alpha_{4,E,PC} = \frac{1}{4}\sum_{t=2012}^{2015} \alpha_{4,Yr}$ = -2.20 for private cars and $\alpha_{4,E,CC}$ = -7.28 for company cars.

Table 7 Average treatment effects for the registration tax

Property regime	Reduced model	Expanded model	Difference
Private car	-1.53	-2.20	0.67
Company car	-6.69	-7.28	0.59

The differences in average treatment effects are summarized in Table 7.

Under the assumption that the extended model is the "correct" one, the failure to account for the parallel trends leads to an error in the estimate of the average treatment effect compared to the average time trend in the ROB that is $\frac{\alpha_{4,R,PC}-\alpha_{4,E,PC}}{\alpha_{3,E,PC}}$ = -2.96% for private cars and $\frac{\alpha_{4,R,CC}-\alpha_{4,E,CC}}{\alpha_{3,E,CC}}$ = -1.55% for company cars. These are small values. Moreover, given that the coefficient of the time trend is not statistically significant, we can conclude that we can safely use the reduced model and thus that the reform of the registration tax has caused an accelerated decrease in the CO_2 emission factors of new cars sold in Flanders, with $\frac{\alpha_{4,R,PC}}{\alpha_{3,R,PC}}$ = 6.81% for private cars and $\frac{\alpha_{4,R,CC}}{\alpha_{3,R,CC}}$ = 17.59% for company cars.

However, it should also be noted that the size of the effect is rather small compared to the trend in the ROB. This is easily understood once we take into consideration the following elements: (a) even after the reform, the correlation between the registration tax in Flanders and the registration tax in the ROB remained positive (0.49 in 2012) (b) on average, the registration tax represents barely 1 to 2% of the purchase cost of new cars – see Franckx (2023), Annex 3.

[13] An alternative possibility is to perform a placebo test: to test whether we observe a faster decrease in CO_2 emission factors in Flanders where we would not expect one if our causal model is correct. In this specific case, we would re-estimate the model, but taking 2007 to 2010 as hypothetical pivot years for the change in trends rather than 2012, and taking again 2015 as last observation year. If the α_3 are statistically significant, then the accelerated decrease in CO_2 emissions in Flanders had already set in before 2012.

6.2. Difference-in-differences model for the annual road tax and the premium for zero emission cars

Our approach to test the causal impact of the reform of the annual road tax and of the premium for zero emission cars is identical to the approach for the reform of the registration tax, except that we need to modify the time frame.

The "before" time period includes all the years from the reform of the registration tax to the reform of the annual road tax (2012 to 2016), while the "post" period includes all the years from the reform of the annual road tax and the introduction of the premium to the end of the eligibility period for the premium (2016 to 2020).

Table 8 DiD Model for the annual road tax and the premium for zero-emission cars

	Private cars: reduced model	Company cars: reduced model	Private cars: expanded model	Company cars: expanded model
α_0	123.61 ***	121.95 ***	123.30 ***	121.63 ***
	(0.41)	(0.18)	(0.43)	(0.20)
α_1	6.91 ***	10.22 ***	12.01 ***	20.41 ***
	(0.17)	(0.19)	(1.97)	(2.32)
α_2	0.20 ***		0.20 ***	
	(0.02)		(0.02)	
$\alpha_{3,2013}$	-3.85 ***	-3.81 ***	-3.64 ***	-3.61 ***
	(0.22)	(0.25)	(0.24)	(0.25)
$\alpha_{3,2014}$	-6.64 ***	-6.89 ***	-6.23 ***	-6.47 ***
	(0.23)	(0.25)	(0.28)	(0.26)
$\alpha_{3,2015}$	-9.34 ***	-11.12 ***	-8.73 ***	-10.48 ***
	(0.23)	(0.24)	(0.33)	(0.28)
$\alpha_{3,2016}$	-10.68 ***	-12.62 ***	-10.38 ***	-12.30 ***
	(0.29)	(0.26)	(0.31)	(0.27)
$\alpha_{3,2017}$	-10.67 ***	-11.98 ***	-10.37 ***	-11.66 ***
	(0.30)	(0.26)	(0.32)	(0.27)
$\alpha_{3,2018}$	-7.76 ***	-7.17 ***	-7.46 ***	-6.85 ***
	(0.30)	(0.26)	(0.32)	(0.27)
$\alpha_{3,2019}$	-4.29 ***	-5.40 ***	-4.00 ***	-5.08 ***
	(0.31)	(0.25)	(0.33)	(0.26)
$\alpha_{4,2016}$	-0.51	-3.48 ***	0.46	-1.61 **
	(0.35)	(0.40)	(0.51)	(0.58)
$\alpha_{4,2017}$	-1.34 ***	-6.15 ***	0.01	-3.54 ***
	(0.35)	(0.39)	(0.62)	(0.71)
$\alpha_{4,2018}$	-1.38 ***	-5.49 ***	0.34	-2.12 *
	(0.35)	(0.39)	(0.75)	(0.86)
$\alpha_{4,2019}$	-3.26 ***	-6.74 ***	-1.16	-2.61 **
	(0.36)	(0.39)	(0.89)	(1.01)
α_5			-0.38 **	-0.75 ***
			(0.15)	(0.17)
N	277613	218315	277613	218315
R2	0.03	0.04	0.03	0.04

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

The reduced model estimates can be found in the two left columns of Table 8.

We observe the following points, both for private cars and company cars.

First, all estimated coefficients are highly significant, except for $\alpha_{4,Yr}$ for private cars in 2016. Second, the sign of α_1 implies that, in 2015, average CO_2 emissions per km were higher in Flanders than in the ROB (even after controlling for income in the case of private cars). Third, $\alpha_{3,Yr} < 0$ for $Yr = 2012,\ldots,2019$, while $\alpha_{4,Yr} < 0$ for $Yr = 2016,\ldots,2019$. $\alpha_{4,Yr}$ is not significant for private cars in 2016.

From 2016 to 2019, the average value for the time-dummies in the reduced model is $\alpha_{3,R,PC} = \frac{1}{4}\sum_{t=2016}^{2019}\alpha_{3,Yr}$ = -8.35 for private cars and $\alpha_{3,R,CC}$ = -9.29 for company cars. In other words, after the reform of the annual road tax in Flanders and the introduction of the premium for zero-emission cars, CO_2 emissions factors of new cars decreased more quickly in Flanders than in the ROB.

The average treatment effect in the reduced model is $\alpha_{4,R,PC} = \frac{1}{4}\sum_{t=2016}^{2019}\alpha_{4,Yr}$ = -1.62 for private cars and $\alpha_{4,R,CC}$ = -5.46 for company cars. Note that $\frac{\alpha_{4,R,PC}}{\alpha_{3,R,PC}}$ = 19.41% for private cars and $\frac{\alpha_{4,R,CC}}{\alpha_{3,R,CC}}$ = 58.80% for company cars.

The expanded model estimates can be found in the two right columns of Table 8: $\alpha_5 < 0$ and statistically significant, both private cars and company cars. As the result of the inclusion of the $Time\ RgFl$ term, none of the estimated α_3 is significant for private cars. For company cars, the estimated α_3 remain significant but their absolute value is much smaller than in the reduced model.

Table 9 Average treatment effects for the annual road tax and the premium for zero-emission cars

Property regime	With differential linear trend	Without differential linear trend	Difference
Private car	-1.62	-0.09	-1.53
Company car	-5.46	-2.47	-2.99

The effects on the average treatment effects are summarized in Table 9.

Under the assumption that the extended model is the "correct" one, the failure to account for the parallel trends leads to an error in the estimate of the average treatment effect compared to the average time trend in the ROB that is $\frac{\alpha_{4,R,PC}-\alpha_{4,E,PC}}{\alpha_{3,E,PC}}$ = 19.04 % for private cars and $\frac{\alpha_{4,R,CC}-\alpha_{4,E,CC}}{\alpha_{3,E,CC}}$ = 33.36 % for company cars.

Summarizing, for privately owned cars, we find no statistically significant effect in 2016 following the reform of the annual road tax and the introduction of the premium for zero-emission cars. In the expanded model, no significant effects can be found at all. In the case of company cars, we do find a statistically significant effect but failing to consider a separate time trend for Flanders that already set in before the reform in 2016 leads to an important overestimation of the impact of the reform.

It is straightforward to understand this result: the reform of the registration tax in 2012 had already created incentives for an accelerated reduction in CO_2 emission factors in Flanders, both for private and for company cars. Moreover, we have seen that the correlation between the annual road taxes in Flanders and the annual road taxes in the ROB remained very high, even after addition of the two correction factors. Our analysis has shown that the additional effect of the reform of the annual road tax is much smaller than that of the registration tax, and not even significant in the case of private cars.

7. Conclusion

We have seen that, over the period 2012-2015, the reform of the registration tax has indeed *caused* an accelerated decrease in the CO_2 emission factors of new cars sold in Flanders, compared to other regions. This result holds for privately owned cars as well as for company cars.

As a result of the reform, the CO_2 emission factors of new private cars in Flanders decreased by 1.53 gr per km compared to a counterfactual without reform of the registration tax. In the case of company cars, the difference was 6.69 gr per km. This additional decrease equalled 6.81% of the decrease in the rest of Belgium in the case of private cars, and 17.59% in the case of company cars.

There are two factors that help us understand why the overall impact was relatively modest: (a) even though the Flemish reform involved a completely different approach to calculating the registration tax, the parameters determining the tax are positively correlated with the parameters determining the registration tax in the ROB (b) the registration taxis really small compared to the purchase price of new cars.

The additional effect of the reform of the annual road tax and of the introduction of the premium for zero-emission cars is even smaller than for the registration tax, and not even significant in the case of private cars. Again, this outcome is straightforward to understand if one considers the following elements: (a) The reform of the registration tax in 2012 had already created incentives for an accelerated reduction in CO_2 emission factors in Flanders, both for private and for company cars. (b) Even after the reform, the correlation between the annual road taxes in Flanders and the annual road taxes in the ROB remained very high.

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