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Article

Encouraging Environmentally Friendlier Cars via Fiscal Measures: General Methodology and Application to Belgium

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Abstract: In this paper, a Belgian tax reform plan is elaborated to respond to the EU proposal that requires member states to restructure passenger car taxation systems, preferentially based on the CO_2 emissions of the car. A tax orientation on CO_2 emissions alone might however favour diesel vehicles, characterised by a higher fuel efficiency, whereas they release more polluting emissions (PM and NO_x) than comparable gasoline vehicles. This paper introduces a methodology, the Ecoscore, as a potential tax assessment basis. The Ecoscore is based on a well-to-wheel framework and enables a comparison of the environmental burden caused by vehicles with different drive trains and using different fuels. A new proposal for a fixed vehicle taxation system, based on the Ecoscore, is launched. In addition, its impact on the life cycle cost of conventional as well as alternative fuelled cars is measured in order to examine its steering effect towards a cleaner vehicle choice. The overall result is that current tax distortions can be corrected by restructuring the vehicle registration tax and annual circulation tax, based on the Ecoscore. To stimulate behavioural changes, such a fiscal policy should however be paired with additional policies that act on the other important aspects that determine the car purchase decision.

Keywords: annual circulation tax; Ecoscore; life cycle cost analysis; tax reform; vehicle registration tax

Abbreviations

B5	5% biodiesel
B10	10% biodiesel
B30	30% biodiesel
B50	50% biodiesel
B100	100% biodiesel
CNG	compressed natural gas
D	diesel
D PM	diesel with PM-filter
E5	5% ethanol
E10	10% ethanol
E20	20% ethanol
E85	85% ethanol
EV	electric vehicle
HEV	hybrid electric vehicle
LPG	liquified petroleum gas
P	petrol

1. Introduction

Reducing the use of fossil fuels for road transport is currently one of the most important sustainability objectives of the European Union [1]. Road transport not only generates about one fifth of European carbon dioxide (CO_2) emissions, but also largely contributes to the release of other pollutants, including nitrogen oxides (NO_x), non-methane hydrocarbons (NMHC) and particulate matter (PM).

In addition to policy measures at the EU level, member states are encouraged to apply a range of fiscal measures to reduce CO_2 emissions from passenger cars. In 2005, the European Commission (EC) launched a proposal for a Council Directive that requires member states to restructure their passenger car taxation systems [2]. The aim of this proposal is twofold. First, it hopes to improve the functioning of the internal market by eliminating existing tax obstacles such as double taxation, tax-induced cross-border transfer of cars, distortions and inefficiencies. Secondly, it aims to promote sustainability by restructuring the vehicle registration tax (VRT) and the annual circulation tax (ACT) linked to the CO_2 emissions of the car [2]. The proposal does not intend to harmonise tax rates; it rather aims to restructure existing systems without obliging member states to introduce new taxes. The EC sees fiscal measures as a strong incentive to steer consumer behaviour towards more energy-efficient passenger cars and as a powerful tool to encourage the introduction of the cleanest light-duty vehicle classes into the market [3].

In response to the EU proposal, 15 European countries have already applied taxation schemes correlated with the CO_2 emissions and fuel consumption of the car [4]. In Belgium however, vehicle taxes are still based on the performance of the vehicle. The VRT, which is levied once-only upon the registration of a brand new or second-hand vehicle, is currently based on the power of the vehicle expressed in kilowatts (kW) and in fiscal horsepower (HP). The ACT is based on the fiscal HP, which is derived from the engine displacement of the vehicle (cc) [5]. To be in line with European Union policy, the Belgian government should introduce a reform of the vehicle taxation system. In Belgium, on a total of more than five million vehicles there are only around 1,000 electric vehicles, 16,000 hybrids and 30 plug-in hybrid vehicles. They can be charged via 200 (semi-)public charging stations. LPG vehicles represents less than 1% of the car fleet.

As most vehicle and fuel tax regimes are designed to generate revenues rather than environmental enhancement, a CO_2 differentiated passenger taxation system, as suggested by the EC [1], is an important step towards considering environmental repercussions in levying taxes [6]. However, orienting taxes on CO_2 emissions alone might give diesel vehicles an advantage as a result of their higher fuel efficiency, whereas they release more PM and NO_x than comparable petrol vehicles. Yet, the European Commission states that the tax reform should be non-discriminatory between specific types, classes or segments of cars and technologically neutral. Moreover, it should let the polluters pay for the environmental damage they cause [“polluter pays principle” (PPP)].

The present paper introduces a new environmental metric, the Ecoscore, as a potential taxation basis. The Ecoscore is based on a well-to-wheel (WTW) framework and enables a comparison of the environmental burden caused by vehicles with different drive trains and using different fuels [7]. Based on this indicator, a new tax regime will be elaborated against which the current vehicle taxation system and the CO_2-differentiated proposal (initiated by the EC) can be compared in terms of their contribution to the PPP.

In order to analyse the extent to which this new tax regime can promote a sustainable vehicle choice, a life cycle cost (LCC) model will be elaborated. A LCC analysis takes all costs related to the purchase and use of the car for the end-user into consideration. As such, it can be used to assess the financial attractiveness of alternative and conventional fuelled vehicles in the existing and new fiscal system. The advantage of using a LCC is that, besides taxation, it covers the three most important financial aspects that determine the car purchase decision, namely purchase price, fuel consumption and maintenance costs [8].

Overall, the principle objectives of this paper are two-fold. First, the LCC model is designed to evaluate the cost-efficiency and tax treatment of clean vehicles (Section 2) and the extent to which differentiated taxation can enhance their financial attractiveness (Section 4). Second, the Ecoscore is introduced which allows an investigation of the correspondence between total taxes and the environmental performance of each individual car (Section 3). The insights from Sections 2 and 3 are then merged into the new proposal for reform (Section 4). The discussion and conclusions are formulated in Section 5.

2. Life Cycle Cost Analysis

2.1. Methodology

LCC analyses have been widely applied to calculate the retail and LCC of hybrid electric vehicles (HEV) [9], to assess the cost-efficiency of alternative fuels and drive trains in Thailand [10], to examine the economic feasibility of hydrogen as an alternative fuel [11], to calculate the cost-efficiency of an electric vehicle (EV) *versus* a petrol-powered vehicle [12] and to make a techno-economic comparison of series hybrid, plug-in hybrid, fuel cell and regular cars [13].

A detailed car LCC spreadsheet model has been elaborated to analyse the cost-efficiency and the differences in tax treatment of new, privately owned conventional and alternatively fuelled cars. It is assumed that a new car remains in the possession of the initial owner for seven years, which is the average period of ownership prior to a first change in car ownership in Belgium [14]. An annual vehicle mileage of 15,000 km is considered, which is the average annual distance driven in Belgium by the entire passenger vehicle fleet over the last 10 years [15]. This average mileage is used in order to have a comparative basis. Note that diesel vehicles are often used for higher mileages. The LCC model integrates all anticipated costs associated with the ownership and use of the car by applying the net present value method [Equation (1)]:

$$PV = A_t * \frac{1}{(1+i)^T} \tag{1}$$

where PV stands for the present value; at represents the cost at time t, T gives the depreciation time (expressed in number of years) and i reflects an interest rate of 4%. This interest rate is the average rate of return for private investments and renders the consumer opportunity cost of purchasing a car relative to alternative uses of the same money [3,16–18]. It is also the standard discount rate applied in other LCC analyses and social cost-benefit analyses [9].

The LCC of each car is calculated in three steps. First, every stream of costs is analysed. Then, the discounted PV of future costs is calculated and finally, an annuity factor is applied to convert the total costs to annual costs, assuming an initial car ownership of seven years [18,19]. This enables a comparison of different vehicle types (supermini, small city car, small family car, large family car, exclusive car, SUV), fuel [petrol (P), diesel (D), liquified petroleum gas (LPG), compressed natural gas (CNG), ethanol (E), bio-diesel (B)] and technologies (internal combustion engine (ICE), EV, HEV) in terms of their cost-efficiency and tax treatment. For each vehicle type, a reference petrol car is chosen for which comparable alternative fuel and drive train vehicles (AFVs), in terms of performance (cc), power (kW) and acceleration time from 0 to 100 km/h) and standard equipment, are currently (or nearly) available on the market.

The LCC is based on several cost parameters (depreciation, insurance, maintenance, vehicle taxation and fuel) and is applied to the case of Belgium [20]. These cost parameters are outlined below and summarised in Table 1.

Table 1. Key cost parameters.

Vehicle type	Make/model	Fuel	Purchase price (€)	VRT (€)	ACT (€/year)	Fuel consumption (l/100 km; m^3/km; kWh/km)	Insurance (€/year)	Maintenance (€/year)
Supermini	Citroën C1	P	9,446	62	126	4.5	793	1,067
Supermini	Citroën C1	D	11,896	62	204	4.1	680	1,067
Supermini	Citroën C1	LPG	11,446	0	215	5.7	793	1,127
Supermini	Citroën C1	EV	35,756	62	70	0.12	793	846
Small city car	Fiat Punto	P	14,720	62	204	5.8	804	1,074
Small city car	Fiat Punto	D	14,300	62	165	4.5	804	1,084
Small city car	Fiat Punto	LPG	14,560	0	254	7.4	804	1,144
Small city car	Fiat Punto	CNG	16,810	62	254	6.5	725	1,144
Small family car	Nissan Leaf	EV	32,829	62	70	0.15	881	941

Table 1. *Cont.*

Vehicle type	Make/model	Fuel	Purchase price (€)	VRT (€)	ACT (€/year)	Fuel consumption (l/100 km; m^3/km; kWh/km)	Insurance (€/year)	Maintenance (€/year)
Small family car	Citroën C4	P	16,586	62	204	6.4	881	1,162
Small family car	Citroën C4	D PM	18,286	123	243	4.7	881	1,162
Small family car	Citroën C4	B5	18,286	123	243	4.7	881	1,162
Small family car	Citroën C4	B10	18,286	123	243	4.8	881	1,162
Small family car	Citroën C4	B30	18,486	123	243	4.8	881	1,162
Small family car	Citroën C4	B100	18,486	123	243	5.2	881	1,162
Small family car	Honda Civic IMA	HEV	22,390	62	165	4.6	878	1,097
Large family car	Renault Fluence	EV	20,000	62	70	0.15	1021	1,036
Large family car	Toyota Prius	HEV	26,830	62	204	4.3	833	1,170
Large family car	Volvo V50	D PM	33,050	495	373	5.7	1,021	1,275
Large family car	Volvo V50	P	30,600	495	281	7.3	1,021	1,275
Large family car	Volvo V50	E5	30,600	495	281	7.5	1,021	1,275
Large family car	Volvo V50	E10	30,600	495	281	7.6	1,021	1,275
Large family car	Volvo V50	E20	31,600	495	281	7.9	1,021	1,275
Large family car	Volvo V50	E85	31,600	495	281	9.9	1,021	1,275
Exclusive car	Mercedes S	P	106,722	4,957	2,368	11.7	1,272	1,422
Exclusive car	Mercedes S	D PM	98,978	4,957	1,784	9.4	1,272	1,422
Exclusive car	Mercedes S	LPG	107,722	4,659	2,576	14.8	1,272	1,482
Exclusive car	Lexus LS	HEV	113,750	4,957	2,173	9.2	1,272	1,304
SUV	Mercedes M	P	57,354	4,957	1,351	11.1	1,272	1,422
SUV	Mercedes M	D	55,055	4,957	700	9.4	1,206	1,422
SUV	Mercedes M	D PM	55,781	4,957	700	9.4	1,206	1,422
SUV	Mercedes M	LPG	58,354	4,659	1,567	14.1	1,272	1,482
SUV	Lexus RX	HEV	61,180	4,957	1,351	8.1	1,172	1,304

Notes: Insurance and maintenance costs are 2007 figures, adjusted to 2010 figures using the consumer price index (FPS Finance, [21]). Purchase prices include standard offered equipment [22].

2.1.1. Depreciation Costs

Purchase costs of the conventional vehicles (and additional equipment such as a PM-filter) are based on automobile retail websites [2]. Vehicles on alternative fuels (LPG, CNG, biofuels) require additional conversion costs to make them fuel compatible. An LPG and CNG retrofit to the reference petrol vehicle amounts up to respectively 2,000 and 2,500 Euros. Vehicles driving on low blends of biofuels (E5, E10, B5, B10) are compatible to all existing vehicle engines and require no additional costs. Vehicles driving on high blends of biodiesel (B30, B100) and ethanol (E20, E85) need dedicated vehicles with surplus costs of respectively 200 and 1,000 Euros (flexi-fuel vehicles). EVs, like Citroën C1 EV and Nissan Leaf, consist of a lithium-ion battery package with a limited driving range of 130 km. Many uncertainties currently exist with respect to the lifespan of lithium-ion batteries, which is measured in terms of charge and discharge cycles. Much will depend on the depth of discharge, the effect of temperature on the electrochemical processes within the battery and the discharging rate. In this analysis, it is assumed that no battery replacements will take place, which is rather optimistic.

Other producers of EVs, like the Renault Fluence, offer battery leasing at 100 Euros/month. For HEVs, a 7.5 battery life is taken into consideration, as warranty periods for the battery are typically 7 to 8 years [9].

Vehicles depreciate over time. Loss of value due to depreciation is in the first few years of a vehicle's life a very critical cost parameter. Depreciation rates vary not only along the used fuel or drive train, but also according to the brand image, new model pricing, mileage range, comfort and convenience features and vehicle class [23]. In this analysis, the deprecation cost is based on the used fuel and/or drive train and excludes other sources of variation amongst makes and types. As a result, depreciation costs of makes with a high resale value, such as German makes, might be overestimated. The total percentage written off after seven years time is 79% for petrol and biofuels, 74% for diesel, 82% for LPG, 83% for CNG and 84% for EV [24].

2.1.2. Insurance

Legally, the civil liability premium is mandatory in Belgium. This premium is based on three parameters: living area, age, and bonus-malus which reflects the driving experience and accident rate of the main driver. Additionally, the civil liability premium can be complemented with an omnium insurance, which fully depends on the actual value of the car. This is not included in the analysis as it already covers a part of the depreciation, so as to avoid double counting [25].

2.1.3. Vehicle Taxes

The vehicle lifetime cost is also determined by the vehicle taxation system. Here, the Belgian taxation system is used as an example. In Belgium, three kinds of taxes apply [5]:

Acquisition taxes, comprising a value-added tax (VAT) of 21% on the net purchase price and a VRT, which is currently based on the power of the vehicle (kW). This VRT is levied once-only upon the registration of the vehicle and is further reduced for LPG and CNG vehicles (minus 298 Euros). EVs get the minimum VRT (61.5 Euros). At the acquisition of a new car, vehicles with low CO_2 levels (respectively lower than 105 g/km; and between 105–115 g/km) receive a reduction of their purchase price (respectively 15% and 3%). EVs even get a special reduction of 30% up to 2012 (via tax deduction). A reduction of 210 Euros (indexed amount 2010) can be obtained when purchasing a diesel vehicle, standard equipped with a PM-filter and with a CO_2 level lower than 130 g/km [5].

Ownership taxes, represented by the ACT which is currently based on the fiscal HP, derived from the engine displacement of the vehicle (cc). LPG and CNG vehicles pay a compensating ACT, whereas for EVs the ACT is reduced to the minimum (69.7 Euros/year).

User taxes, referring to the VAT (21%) and excises applied on fuels.

2.1.4. Maintenance Costs

Maintenance costs include tyre costs, costs for small and large maintenance and costs for annual car inspection [26,27]. Tyre costs depend on vehicle type and annual mileage and are assumed to be replaced at a mileage of 50,000 km [26]. Costs for small and large maintenance are viewed as costs to keep the vehicle operational including oil replacement, revision of brakes *etc.* Compared to the reference petrol vehicle, maintenance costs for EVs are low because electric motors contain less moving components, face less temperature stress and oil and filter replacements are not necessary [12,13].

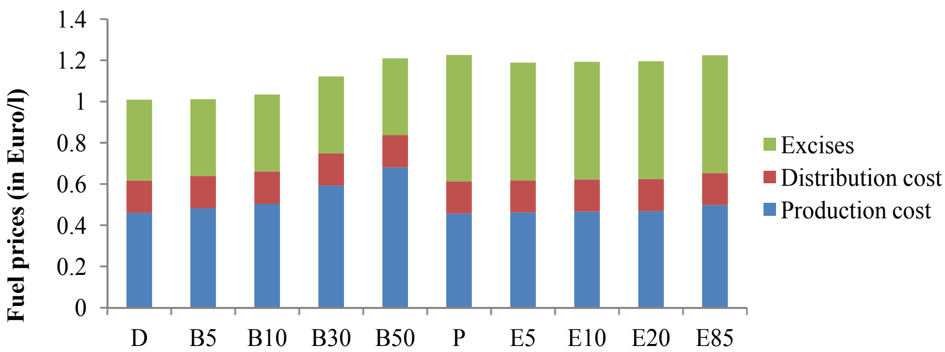
Estimations of maintenance costs for HEVs vary from 15% higher to 25% lower than the reference petrol vehicle [12,28]. In line with [10], maintenance costs for HEVs are considered the same as for the reference ICE vehicle.

Annual car inspection is obligatory for all vehicles aged four years or older. Annual car inspection costs comprise a base price of 27.5 Euros, complemented with an environmental inspection (+10.5 Euros for ICE; 3.5 Euros for electric propulsion systems) and an additional inspection for LPG and CNG installations (15 Euros) [27].

2.1.5. Fuel Costs

Fuel prices for conventional vehicles are based on maximum fuel prices in Belgium: 1.24 Euros/L for diesel and 1.50 Euros/L for petrol [29]. This includes a VAT and excise duties (0.39 Euros/L for diesel and 0.61 Euros/L for petrol). LPG and CNG are exempted from paying excises. Their fuel prices, including VAT, amount up to 0.54 Euros/L LPG and 0.90 Euros/kg CNG [29]. Petrol and diesel blended with an amount of biofuels originating from Belgian biofuel plants get a small excise reduction (0.37 Euros/L for bio-diesel blends and 0.57 Euros/L for ethanol blends) [30]. Untaxed prices of biofuels depend on many factors (raw materials, capital cost, intermediary processing and logistics). In this analysis, production prices of 0.55 Euros/L for ethanol and 0.90 Euros/L for bio-diesel are taken into consideration, based on the ethanol price on the Rotterdam market and bio-diesel prices on the German market [31]. The higher the percentage of biofuel in the blend, the higher total fuel costs/L will be (see Figure 1). Electricity from the grid is not taxed as a transport fuel. The exact electricity price depends on many factors, such as separate day and night prices. Here, a variable home-use tariff is used which is 0.15 Euro/kWh (including VAT) [32].

Figure 1. Breakdown of biofuel prices. (Source: Lievens and Jossart [31], Petrolfed [29]).

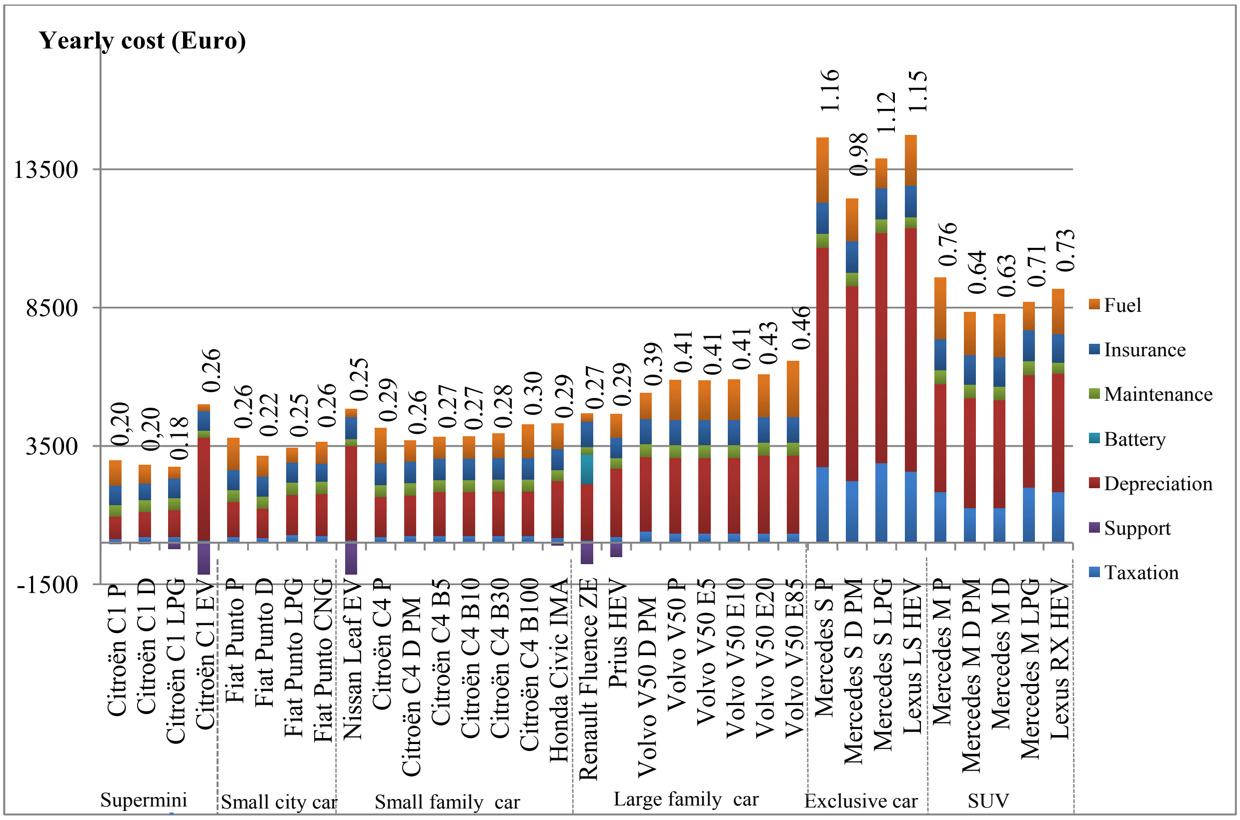


Total fuel costs are determined by fuel price and fuel consumption. Where available, the officially reported fuel consumption, based on the new European driving cycle (NEDC) is used. For other vehicles (e.g., biofuels, EVs), no official figures on energy consumption exist as they are not released on the market yet. The fuel consumption of biofuel vehicles is based on the energy density of the fuel and the percentage of biofuel in the blend [10,33]. Vehicles on E20 and E85 consume respectively 8% and 35% more than the baseline petrol vehicle, whereas B30 and B100 have a smaller surplus consumption (respectively 3 and 10%) with respect to a diesel vehicle as a result of the higher energy density of biodiesel as compared to ethanol [34]. For EVs, energy consumption is based on prototypes, communicated by vehicle manufacturers.

2.2. Results

Figure 2 displays the cost-efficiency and the differences in tax treatment per km for the AFVs and reference petrol vehicles. Initially, a large dispersal of the results over different vehicle types is shown. Vehicles can have a yearly cost of 3,000 (supermini) to more than 17,000 Euros (exclusive car), with a cost per person km travelled that varies from 0.18 Euros (supermini) up to 1.16 Euros (exclusive car). Depreciation costs represent the greater part of the yearly costs, followed by fuel costs (including VAT and excises), insurance, maintenance costs (including car inspection, costs for small and large maintenance and tyre costs) and fixed vehicle taxation (VRT and ACT). Vehicles with emissions lower than 105 g CO_2/km receive a subsidy of 15% of the purchase price. For electric vehicles this is 30%.

Figure 2. Life cycle cost in current vehicle taxation system.



Notes: The cost per km (€/km) is indicated above each bar.

Within each vehicle type, diesel vehicles show the greatest cost-efficiency on a per km basis as compared to the reference petrol vehicle, which is mainly the result of differences in fuel-efficiency (20%–30% more efficient than petrol engines) and fuel taxation (almost 40% less excises than on petrol fuel). This cost-efficiency has led to a greater proliferation of diesel vehicles in Belgium (79% of all new car purchases in 2009 were diesel-based) and elsewhere in Europe [35]. Diesels are known to emit more PM and NO_x emissions on a per km basis than petrol fuel, which implies that diesel vehicles should be subjected to a higher fuel tax per litre, given the differences in fuel use per km. This would however mean that diesel and petrol vehicles with approximately the same characteristics should face equal fixed vehicle taxes, which would lead to a drastic revision of the current vehicle taxation system. No differentiation in fixed vehicle taxes is currently in place for diesel vehicles with externality-reducing characteristics, such as PM filters, which face a higher cost on a per km basis than conventional diesel vehicles.

Within each vehicle type, AFVs produce more or less competitive costs on a per km basis with respect to the reference petrol vehicle, but are often cost-inefficient with respect to the comparable diesel vehicle. Although biofuels can enjoy a small excise reduction, they are faced with higher fuel taxes on a per km basis as a result of their lower energy density. Unless the imposed excises would be adapted proportional to the amount of biofuels in the blend, biofuel vehicles will not become financially advantageous for end-users. Despite the exemption of excise duties, LPG and CNG vehicles encounter additional conversion costs, a higher deprecation rate, higher annual inspection costs and an additional fixed tax burden. The existing generation of HEVs cannot compete on cost-efficiency with diesel vehicles without additional support. They still face higher purchase prices, lower resale values and encounter more fuel taxes than diesel vehicles, despite their greater fuel efficiency. EVs (like C1 EV) are also at present more expensive than conventional vehicles. Its high cost is particularly the result of its high purchase price (small-scale production) which includes an expensive lithium-ion battery, combined with a higher depreciation rate. The lower maintanance and fuel costs (low untaxed electricity prices) and the minimum vehicle taxation tariffs cannot compensate the vehicle purchase price premium. Its financial attractiveness can nevertheless increase with battery leasing (see for example Renault Fluence).

Overall, these results demonstrate that AFVs are currently not financially attractive for the Belgian end-user and that the current fiscal system not accurately reflects the differences in the environmental performance of vehicles. So acting on the LCC by means of fiscal instruments, differentiated along the environmental performance of the car, could be an effective way to encourage their purchase. Given the existing availability of fiscal instruments, governments could apply differentiated fuel taxes or fixed vehicle taxes [36].

In 2002, the EC suggested a convergence of taxes on diesel and petrol fuels, which was however rejected by the European Parliament [6,37]. Acting on fuel taxes seems to be restricted by several constraints. First, because of its significance to the transport industry, diesel is taxed at a lower rate than petrol in almost all European countries [6]. In the second place, it is difficult to issue separate taxation modalities for diesel fuel used for private or commercial purposes [37]. Thirdly, a fuel tax instrument in Europe is limited because of the proximity of the borders, which might encourage fuel tourism. Finally, fuel taxes may not target non-CO_2 pollutants effectively and cannot be differentiated according to the emission technology of the vehicle [36,38–40].

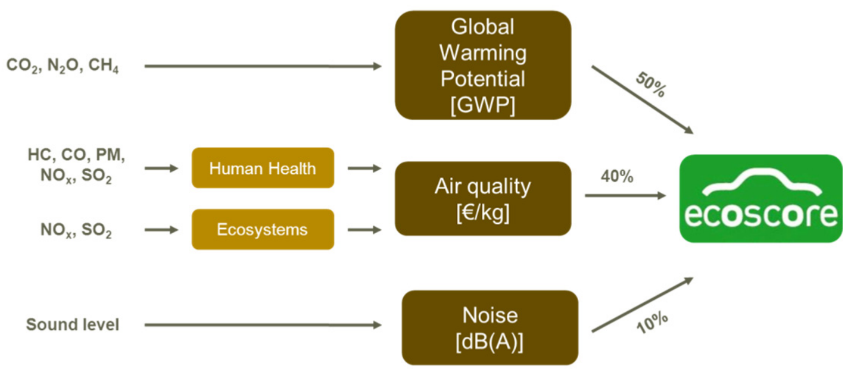
In the presence of these technical and political restrictions, fixed vehicle taxation may become highly relevant in reflecting the differences in the environmental performance of vehicles [39,41,42]. The CO_2 differentiated tax, launched by the EC, is a strong initial step towards countering environmental repercussions. However, by orienting taxes on CO_2 emissions alone, an additional tax advantage might be given to diesel vehicles, whereas CO_2 exhaust from diesel fuel is already implicitly taxed at a lower rate than petrol fuel. Such a provision neglects the fact that these vehicles largely contribute to the release of other pollutant emissions, such as NO_x and PM, which have harmful effects on human health and ecosystems. If the purpose is to incorporate environmental criteria into the vehicle taxation system, CO_2 emissions should not be the sole focus [6]. Ideally, taxes should be based on a complete life cycle assessment (LCA) of the vehicle. An LCA for each individual vehicle, however, requires an extensive set of emission data on all life cycle phases per vehicle, which is not always easy to retrieve. Therefore, a compromise between a complete LCA and a more pragmatic instrument that is transparent and easily applicable on a policy level is required. The next section covers this topic.

3. Ecoscore

3.1. Methodology

The Ecoscore was developed by the Vrije Universiteit Brussel, ULB and VITO for the Flemish government as a policy instrument (for taxation, incentives, consciousness raising campaigns, and so on) to promote the introduction and use of clean vehicles [43]. This environmental metric is based on a "simplified" well-to-wheel (WTW) framework in which tank-to-wheel (TTW) emissions and well-to-tank (WTT) emissions due to the production and distribution of the fuel are taken into account. Neither emissions resulting from the assembly of vehicles and from the production of its constituent elements, nor the maintenance phase and recycling phase of end-of-life vehicles are considered. The main reason for this limitation to a WTW framework is the lack of data availability for all passenger vehicles. Additionally, analyses have shown that the emissions due to the use phase of the cars are decisive compared to those of the production and end-of-life phases [42,43]. Recent research comparing the Ecoscore with a complete LCA of conventional and clean vehicles revealed that the ranking of vehicles regarding their environmental performance is not altered between both assessment methodologies [44]. The environmental evaluation of a vehicle is done according to a sequence of five steps, similar to those used in a standardised LCA: inventory, classification, characterisation, normalisation and weighting (see Figure 3).

Figure 3. Overview of the Ecoscore methodology (Source: [7], adapted by Maarten Messagie (VUB)).



In the inventory step, the TTW emissions (CO, HC, NO_x, PM, CO_2, SO_2, N_2O, CH_4) and WTT emissions (CO, NMHC, NO_x, PM, CO_2, SO_2, N_2O, CH_4) are collected. The classification and characterisation steps analyse their contribution to different damage categories such as global warming, air quality depletion (health impairing effects and effects on ecosystems) and noise pollution.

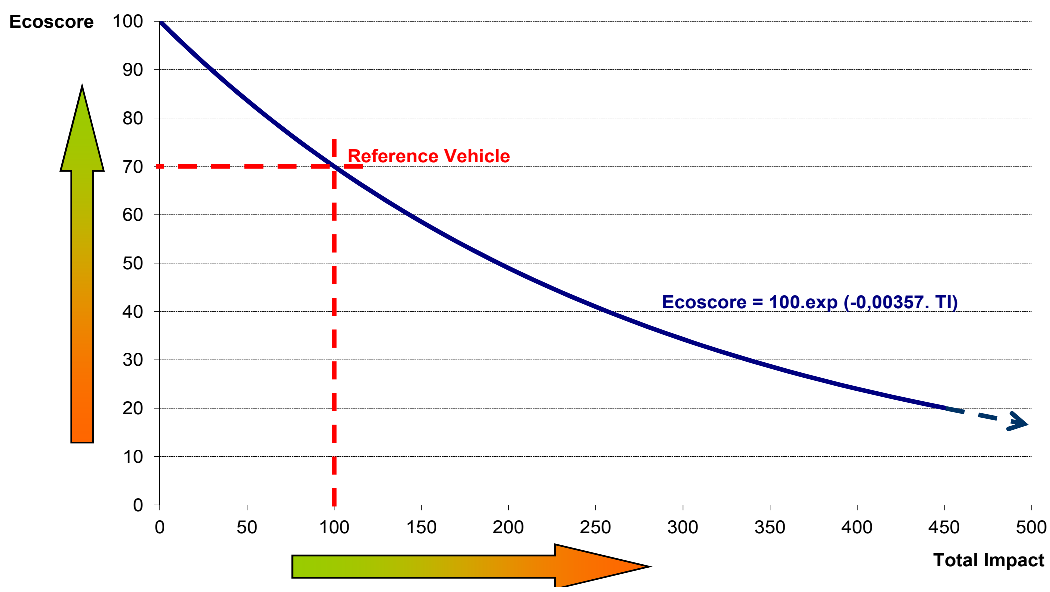
The advantage of using the Ecoscore instead of an environmental external cost calculation is that it does not require the monetary valuation of emissions for which many uncertainties exist. In case of greenhouse gases, the EC handbook [45] recommends values for the external costs of climate change that range significantly according to the methodology used (damage or avoidance cost approach) and the timeframe under consideration (short, medium, long term). Conversely, the Ecoscore calculates the contribution of greenhouse gases using global warming potentials (GWP) as defined by the Intergovernmental Panel on Climate Change (IPCC). External costs were used to calculate the contribution of the inventoried air depleting emissions. Because human health damage is related to the location of the emissions, a weighted average of urban and rural external costs is used, using the Belgian split between urban and rural mileage for passenger vehicles as a weighting factor (25% urban, 75% rural). Noise pollution is expressed in dB(A), a decibel scale with A-weighting, to take the sensitivity of human hearing into account.

To quantify the relative severity of the evaluated damages of each damage category, a normalisation step based on a specific reference value has been performed. The reference point is the damage associated with a theoretical passenger vehicle to which the emission levels correspond with the Euro 4 emission target levels for petrol vehicles, a CO_2 emission level of 120 g/km (the target CO_2 value for the EU by 2012) and a noise level of 70 dB(A).

In a final step, the normalised damages are weighted before they are combined into the total environmental impact (TI) of the vehicle. These weighting factors reflect policy priorities and decision makers' opinions and were determined in consultation with stakeholder groups, including representatives from governmental administrations, political parties, the automotive sector, environmental NGOs and consumer organisations [7].

For clarity, the TI is rescaled into the Ecoscore at a range from 0 to 100, where 100 represents a perfectly clean and totally silent vehicle. The reference value for a clean vehicle corresponds to an Ecoscore of 70. The transformation is based on an exponential function (see Figure 4) to avoid negative scores. Due to this exponential function, the differentiation of Ecoscores is larger for vehicles with a low environmental impact than for those with a high environmental impact.

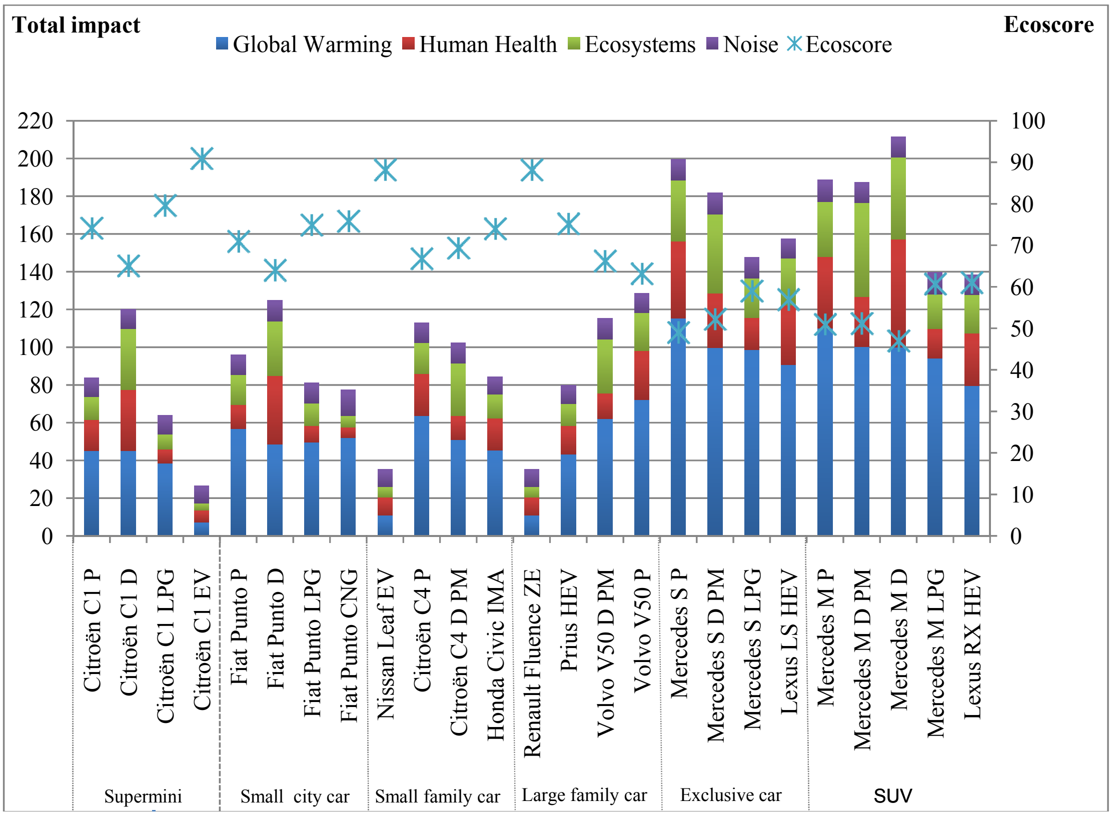
Figure 4. Transformation of total impact to Ecoscore [7].



3.2. Results

Figure 5 displays the TI (divided by damage category) and the Ecoscore for each Euro 4 vehicle included in the LCC analysis. Large differences in the Ecoscore are possible within individual vehicle types. EVs demonstrate the best environmental performance on a WTW basis. The environmental impacts of EVs depend on the driving patterns and electricity production. Within the Belgian context the electricity is produced by more than 55% based on zero emission nuclear power. This explains the low total environmental impact of electric vehicles.

Figure 5. Total impact of the vehicle, split up per damage category.



Notes: Input data are based on official homologation data (CO, NO_x, PM, HC). Other pollutants are correlated with fuel consumption, based on the NEDC (CO_2, N_2O, CH_4, SO_2). Emissions related to production of the fuel (or electricity) are derived from fuel consumption data. Since 2002, homologation data are available for all vehicles brought on the Belgian market. However, up to now, no homologation data exist for biofuel vehicles as they are not commercially available yet. Moreover, the WTT emissions will highly depend on the origin of the biofuel. Due to these data constraints, no Ecoscores currently exist for biofuel vehicles. For EVs, the Ecoscores have been calculated, based on data of prototypes, as reported by vehicle manufacturers.

In addition, by excluding the vehicle production, maintenance and end-of-life stages from the life cycle model, the environmental impact of vehicles is underestimated. However studies revealed that these Life Cycle stages represents about 20% of the total Life Cycle CO_2 emissions [46].

HEVs are also characterised by a low impact on global warming (high fuel-efficiency) and lower levels of air pollutants and noise pollution than those produced by conventional technologies.

Compared to petrol vehicles, the lower impact of LPG and especially CNG vehicles is mainly due to lower WTT emissions combined with lower levels of air-quality-depleting emissions.

Diesel vehicles have a lower impact on global warming than petrol vehicles due to their efficient drivetrains. However, because of the high impact of PM and NO_x on human health, diesel vehicles perform considerably worse than other vehicles in this damage category. Their environmental performance can nevertheless increase with a PM filter (see, for example, the Mercedes M Diesel *versus* Mercedes M Diesel PM).

The results may not be generalised on the basis of technology alone, as the vehicle segment also affects the Ecoscore results; larger segments are associated with worse Ecoscores. In this respect, a small supermini diesel vehicle (e.g., Citroën C1 Diesel) will have a higher Ecoscore than a large petrol-burning SUV (e.g., Mercedes M Petrol).

4. Tax Reform

4.1. Methodology

Because CO_2 emissions should not be the sole basis of taxation, a new tax regime in function of the Ecoscore is elaborated against which the current vehicle taxation system and the CO_2 differentiated proposal (of the EC) can be compared.

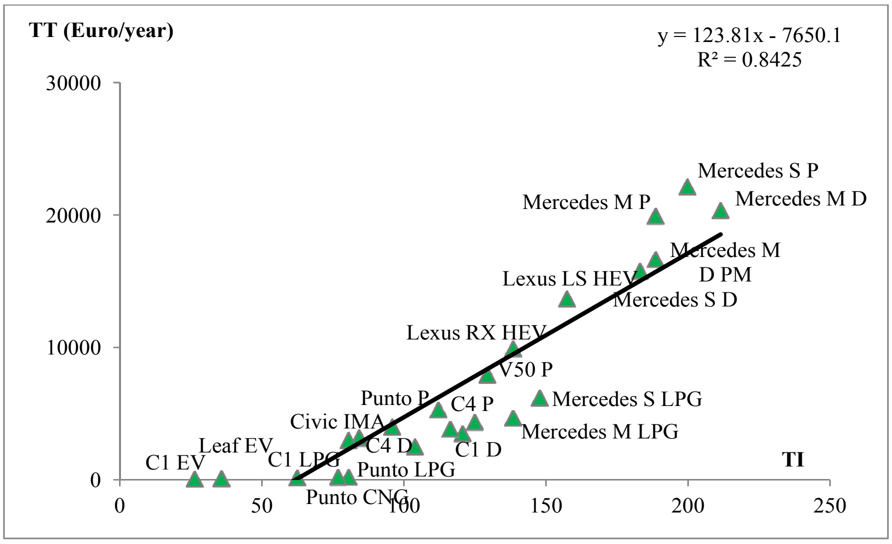
To be in line with the PPP, the total taxation level of the vehicle (TT) (fixed vehicle taxes, fuel taxes) should reflect its environmental performance (Ecoscore). The relative size of the fixed vehicle taxes should thus be determined in accordance with the level of fuel taxes and the environmental impact of the vehicle. A combination of a differentiated tax and a fuel tax can lead to the closest approximation of the external costs of emissions, as both the purchase and usage decision(s) are targeted [39,41,42]. The result is a so-called "WTW" model, as it identifies a targeted "ideal" relation between the TT to be paid during the initial vehicle ownership and the TI, based on the WTW emissions of the vehicle.

The aim of the tax reforms based on the Ecoscore is to bring the TT in line with the TI, as indicated by the projected relation. The new taxation scheme consists of one or more linear functions, based on the TI of the vehicle [see Equation (2)]:

$$TAX = a * TI + b \tag{2}$$

where TAX represents either the VRT or the ACT; TI reflects the total environmental impact of the vehicle (LN (Ecoscore/100)/-0,00357); and "a" and "b" are parameters defined so that polluting cars (Ecoscore < 70) are more heavily charged and cleaner vehicles (Ecoscore > 70) pay less taxes compared to existing taxation levels. The function itself is based on Ecoscore thresholds, which correspond to existing VRT and ACT levels. This example builds on tax functions that have been proposed to the Brussels government, which has considered a tax reformation based on the Ecoscore in 2008 [47,48]. This tax reformation leads to a close approximation of the targeted relation, which is reflected by the tight fit (high R^2) (see Figure 6).

Figure 6. Total taxes (TT) and total environmental impact (TI) of vehicles in Ecoscore-based fiscal system.



4.2. Results

Figure 7 evaluates the current vehicle taxation system in terms of its conformity between TT and the TI of the investigated vehicles. The lower fit (R^2 of 67%) confirms the results of Sections 2.2 (LCC) and 3.2 (Ecoscore): in most of the cases, diesel vehicles are currently under-taxed in relation to their TI (in this example: Citroën C1 D, Fiat Punto D, Mercedes M D, Mercedes M D PM, Volvo V50 D, Citroën C4 D), whereas AFVs (in this example: Lexus LS HEV, Mercedes S LPG, Lexus RX HEV, Mercedes M LPG, Citroën C1 EV, Nissan Leaf EV) are over-taxed during their vehicle useful lifetime (positive residuals). Exclusive cars and SUVs with a higher TI are already more heavily taxed than smaller supermini vehicles with a better TI, which is mainly the result of higher fuel taxes (because of their higher fuel consumption).

Figure 7. Total taxes (TT) and total environmental impact (TI) of vehicles in the existing fiscal system.

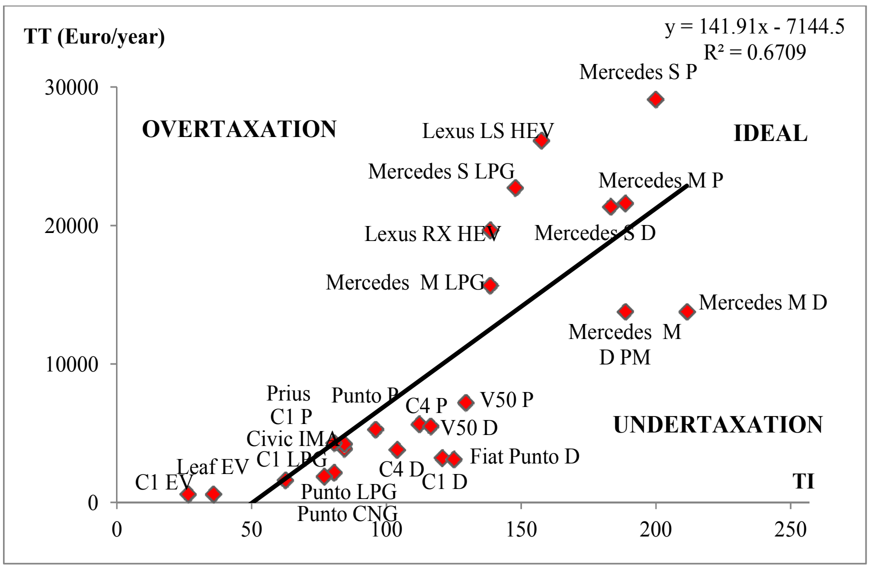
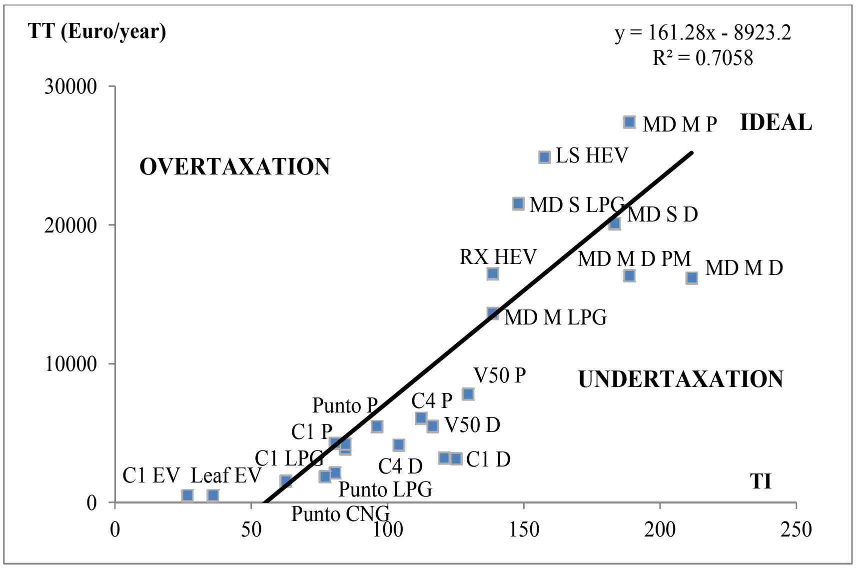


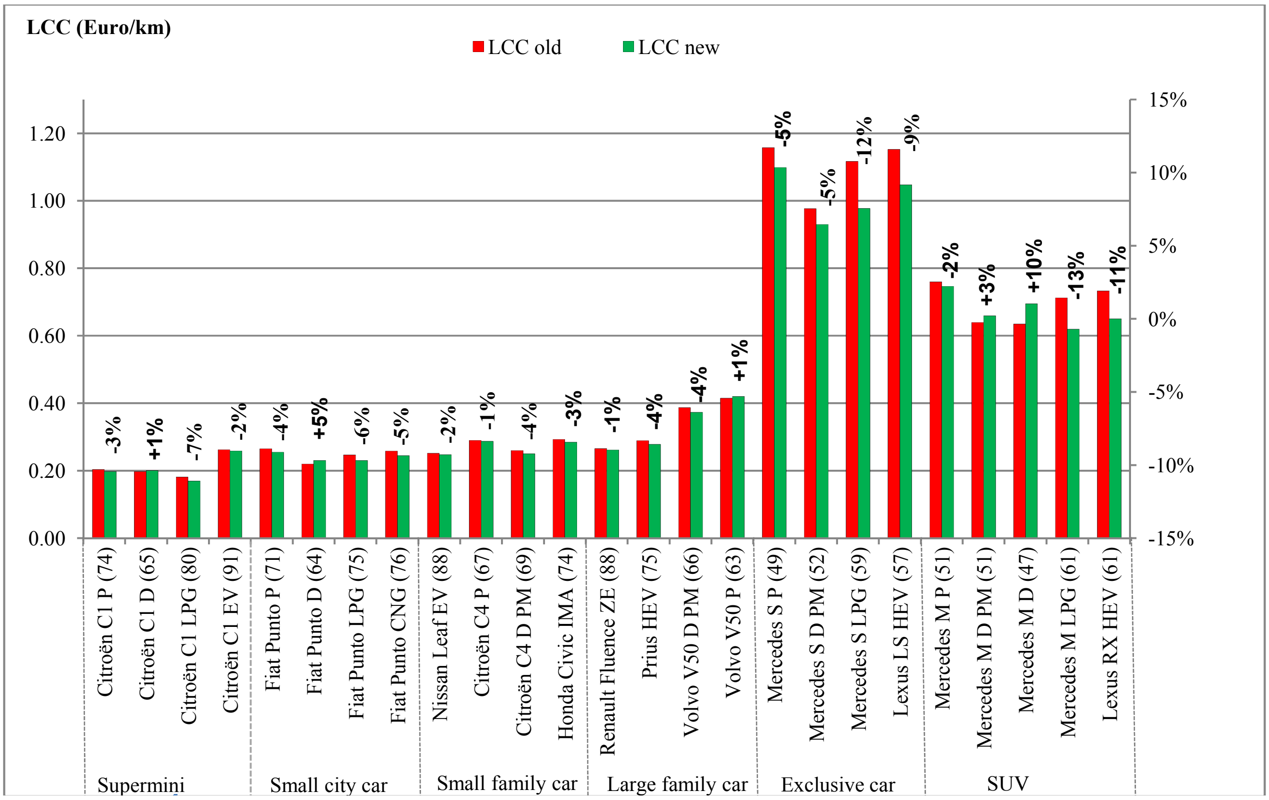
Figure 8 displays the results of a recent budgetary-neutral tax proposal of the Flemish government. (Note that in Belgium; the Flemish, Walloon and Brussels Capital Region are individually responsible for their vehicle taxation system related to passenger cars). In line with the EC proposal, it is based on the CO_2 emissions of the vehicle and supplemented with additional tax arrangements with regard to the Euro standard, the fuel (LPG, P, D) or drivetrain (EV) and the age of the vehicle [49,50]. The tighter fit (R^2 of 71%) shows that the CO_2-differentiated proposal leads to a better alignment between total taxes and the total environmental impact of the vehicle than the current taxation system, but that it performs worse than the Ecoscore-based taxation scheme.

Figure 8. Total taxes (TT) and total environmental impact (TI) in CO_2-differentiated fiscal system.



Based on the comparison of the current taxation system, the EC- and the Ecoscore-based proposal, the latter scheme is found to be the most appropriate to incorporate environmental criteria in the assessment of vehicle-related taxes and hence apply the PPP. The extent to which this Ecoscore-based taxation scheme increases the cost-efficiency of clean vehicles is assessed by means of the percentage change in LCC (see Figure 9). Within each vehicle type, petrol vehicles become less expensive on a cost per km basis (1% to 4%), diesel vehicles without a PM filter face cost increases (up to 10%) and AFVs encounter large LCC reductions (e.g., a 13% reduction for the Mercedes M LPG or an 11% reduction for the Lexus RX HEV), which considerably enhance their cost-competitiveness with respect to conventional diesel vehicles. Note that the overall taxation levels are lower, as only newly bought vehicles are included in this analysis, which already comply with the latest emission limits for exhaust emissions defined by European Union Directives. An entire tax reform should also cover the older, more polluting second-hand vehicles and include special arrangements such as correction factors based on the depreciation of the car, as used vehicles are mainly owned by people who cannot easily access the new vehicle market [6,39].

Figure 9. Life cycle cost in the Ecoscore-based vehicle taxation system.



Notes: The percentage change between the old and new LCC (in Euro/km) is denoted above each bar. The number between brackets represents the Ecoscore.

5. Discussion and Conclusions

This paper developed a LCC tool to evaluate the financial attractiveness of conventionally fuelled cars and cleaner cars in the Belgian context. A particular focus was on the current fiscal system and the extent to which it currently reflects the differences in environmental performances of different vehicle models and technologies. The LCC analysis revealed that clean cars are currently not financially attractive for the Belgian end-user. In order to encourage their adoption, the current fiscal system could be revised in a way that polluting cars are more heavily charged and cleaner cars pay less taxes compared to existing taxation levels. While the case for fuel taxes is strong since it can be administered in a relatively simple way, political and technical constraints point out that it is not a sufficient measure upon which one can base a policy framework. As an alternative (or complementary) policy, a differentiated fixed vehicle taxation has been examined. However, CO_2 emissions (as suggested by the EC) should not be the only basis for a differentiated taxation system. Such a basis not only gives an additional tax advantage to diesel vehicles, which are already implicitly taxed at a lower fuel rate than petrol fuel because of diesel's significance in the transport industry, but it also neglects other important emissions (such as PM and NO_x), which pose harmful effects to health and ecosystems. To incorporate other environmental criteria in the vehicle taxation system, a valuable alternative that offers a compromise between a complete LCA, which relies on extensive data requirements, and a pragmatic instrument that is transparent and applicable on a policy level, is a passenger car taxation system based on the Ecoscore. The Ecoscore is based on a WTW framework and provides an environmental metric on which all technological options can compete. A new tax regime based on a WTW approach has been elaborated in which the relative size of fixed taxes is determined in accordance to the level of fuel taxes and the environmental impact of the vehicles. The overall result is that a combination of fuel taxes and an Ecoscore based taxation system can lead to a better conformity between total vehicle taxes and the total environmental impact of vehicles than when taxation is based on CO_2 emissions alone.

Although Ecoscore-based taxation adds to a better financial reflection of the environmental performance of vehicles, it might not be sufficient to stimulate behavioural change. Even though car buyers' economic concerns are high, their levels of knowledge regarding the actual costs of the car can be low. Limited information or high complexity might prevent consumers from fully investigating the costs and benefits associated with a more sustainable vehicle choice [51]. Because of these market imperfections, people might be less concerned about future fuel savings than about initial vehicle costs facing a higher implicit discount rate. In that case, policy measures acting on fuel costs might be less effective in strengthening the life-time fuel saving linkage to the purchase decision than policy measures acting on the purchase price of the vehicle (e.g., feebate systems) [42,52,53]. Besides financial attributes, consumers might be motivated by other factors as well that are not included in the purely economic model [54]. Uncertainties about technological developments (e.g., fuel/recharging infrastructure) may currently play an important role in the purchase decision of AFVs [55]. In 2020, the market share of PHEVs will be higher than that of BEVs (7% versus 5%). In 2030 a potential market share of 15% for BEVs and 29% for PHEVs is estimated [20]. On the other hand, the purchase of AFVs might appeal to consumers with strong symbolic-affective motivations, such as owning the latest technology (early adopters) or demonstrating a commitment to environmental issues [56,57].

To enhance the adoption of clean vehicles, fiscal measures should thus be paired with other measures that act on other important aspects that determine car purchase decisions. If the tax reform is considered as a potential policy, further research is required to gain more insight into consumer purchase decisions and their price sensitivities following the budgetary implications of the tax reform so as to design a budget-neutral tax reform and to take distributive considerations into account. One should acknowledge that consumers may make choices of vehicles based on factors other than lifecycle costs such as image, brand and so on. Also these factors should be taken into account in order to assess the impact of a tax reform [20].

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