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Life cycle cost analysis of alternative vehicles and fuels in Belgium

Laurence Turcksin[1], Cathy Macharis[1], Nele Sergeant[2], Joeri Van Mierlo[2]
[1]*Vrije Universiteit Brussel, MOSI-T, Pleinlaan 2, 1050 Brussels, laurence.turcksin@vub.ac.be*
[2]*Vrije Universiteit Brussel, ETEC, Pleinlaan 2, 1050 Brussels*

Abstract

This paper investigates whether the vehicle taxation system in Belgium is stimulating the demand of clean vehicle technologies. A life cycle cost analysis will be performed to evaluate the cost-efficiency of several vehicle technologies within the current fiscal system. This life cycle cost will be weighted against the environmental performance of each vehicle to discover the market potential of environmental friendly vehicles and to define necessary fiscal regulations. Additionally, the yearly taxes and external costs (environmental, congestion, accident costs) of each vehicle will be compared, identifying the strenghts and distortions of the Belgian fiscal system with respect to the promotion of clean vehicles. Moreover, it will be examined whether a new vehicle taxation system, based on the environmental performance of vehicles, would be effective in tackling the current distortions while keeping the good incentives for stimulating the demand of clean vehicle technologies. This new vehicle taxation system will be based on a environmental rating tool, the so-called Ecoscore. The Ecoscore enables a comparison of the environmental burden caused by vehicles with different drive trains and using different fuels and is in this respect a very appropriate instrument to introduce a technology neutral reform of the fiscal system. By calculating the tax burden of several vehicles within the current and new fiscal system, it will be assessed whether this new fiscal system is able to evoke a shift in the composition of the vehicle fleet towards a more environmental friendly one.

Keywords: LCC (life cycle cost), car, taxation

1 Introduction

Making a car purchase decision nowadays is very complex, especially when it comes to the evaluation of different alternatives. Besides conventional diesel and petrol vehicles, environmental friendly vehicles on alternative fuels (LPG, CNG, biofuels) or drive trains (hybrid, battery electric) are ready to enter the market. Previous research [1,2] demonstrated that consumers do not take the environmental friendliness of the vehicle into account when purchasing a new car. Although there seems to be a heightened environmental concern, the environmental friendliness of the car is still of minor importance compared to other car attributes such as the purchase price, fuel consumption, and operating costs. As financial factors turn out to be decisional purchase factors, it is interesting to research the actual cost of several vehicle technologies in Belgium and to investigate whether the current vehicle taxation system is stimulating the demand of clean vehicle technologies. In

section 4, a life cycle cost analysis will be performed to evaluate the private consumer costs of several vehicle technologies within the current fiscal system. The purchase of clean vehicle will be a rational economic decision if it provides a lower or equal private consumer cost compared to the conventional petrol or diesel car. By combining this life cycle cost with the environmental performance of each car, a framework will be provided in section 5 to discover the market potential of clean vehicle technologies and to define necessary fiscal regulations. In section 6, the yearly taxes and external costs (environmental, congestion, accident costs) of each vehicle will be compared, identifying the strenghts and distortions of the current fiscal system with respect to the promotion of clean vehicles. Finally, in section 7, it will be examined whether a new vehicle taxation system, based on the environmental performance of vehicles, would be effective in tackling the current distortions while keeping the good incentives for the promotion of clean vehicle technologies in Belgium. This new vehicle taxation system will be based on a environmental rating tool, the so-called Ecoscore. The Ecoscore enables a comparison of the environmental burden caused by vehicles with different drive trains and using different fuels and is in this respect a very appropriate instrument to introduce a technology neutral reform of the fiscal system. By calculating the tax burden of several vehicles within the current and new fiscal system, it will be examined whether this new fiscal system is able to evoke a shift in the composition of the vehicle fleet towards a more environmental friendly one.

2 Methodology

The Life Cycle Cost (LCC) methodology has been chosen to determine and quantify the cost of each vehicle technology. Life cycle costs are all the anticipated costs associated with a car throughout its life and include all the user expenses to own and use vehicles. A vehicle lifetime of 7 years has been assumed, with an annual vehicle mileage of 15.000 kilometres. Only the first owner is considered in the analysis, and not the total vehicle lifespan which is 13.7 years [3]. The LCC for the end-user, or the so-called private consumer costs consist of vehicle financial costs, fuel operational costs and non fuel operational costs. Vehicle financial costs include the purchase price minus governmental supports, opportunity and depreciation costs. The opportunity cost (OC) and depreciation cost (DEP) are being calculated based on the following equations:

$$OC = \frac{(PP - GS)(1+I)^{DT} - (PP - GS)}{(1+I)^{DT}}$$

$$DEP = PP - \frac{PP * (1 - DR)}{(1+I)^{DT}}$$

where PP is the purchase price (+2000 € for LPG; + 2500 € for CNG; +1000 € for E20 and E85), GS are the governmental supports, I is the interest rate (3,9%), DT is the depreciation time (7 years), and DR is the depreciation rate (79% for petrol and bio-fuels; 74% for diesel; 82% for LPG; 83% for CNG and 84% for EV) [4].

Fuel operational costs include the production costs, excises and VAT on the fuel. Non fuel operational costs comprise the yearly taxation, insurance, technical control, tyres and maintenance. In order to accurately combine the initial expenses related to the purchase of the car with the future expenses associated with the use of the car, the net present value method has been used. A real discount rate has been applied to calculate the discounted present value (DPV) of one-time future costs (battery replacements, etc.) and recurring future costs (maintenance costs etc.). The DPV of one-time and recurring costs are calculated using the following equations [5]:

$$DPV = A_t * \frac{1}{(1+I)^T}$$

$$DPV = A_0 * \frac{(1+I)^T - 1}{I * (1+I)^T}$$

where DPV is the discounted present value, A_t is the one-time cost at a time t, A_0 is the recurring cost, I is the real discount rate (2,5 %), and T is the time (7 years).

The LCCs are calculated in three steps. First, every stream of periodic costs is analyzed. Second, the discounted present value of one-time and recurring costs is calculated and finally, this present value is divided by the vehicle mileage driven during the vehicle lifetime to produce a cost per kilometre. As such, the cost-efficiency of several car segments (supermini, small city car, small family car, big family car, small monovolume, monovolume, exclusive car, sports car and SUV), several fuels

(petrol, diesel, LPG, CNG and bio-ethanol) and drive train technologies (internal combustion engine, hybrid electric and battery electric vehicles) can be compared. The purchase of an environmental friendly vehicle will in this respect become a rational economic decision if it provides a lower or equal private consumer cost compared to the conventional petrol or diesel car.

3 Current fiscal system

The LCC calculations are based upon the current fiscal system in Belgium. The Belgian fiscal system consists of taxes related to the purchase, ownership and use of vehicles. Purchase taxes comprise a VAT of 21% on the purchase price and a vehicle registration tax. The vehicle registration tax is levied when registering a brand-new or second-hand vehicle. It is currently based on the power of the vehicle, expressed in kilowatts or in fiscal horsepower. A reduction of 298 Euro can be obtained for LPG and CNG vehicles. The vehicle registration tax diminishes according to the age of the vehicle. Once a vehicle is fifteen years old, a minimum registration tax of 61,5 Euro has to be paid. The Belgian government is currently providing a reduction for the purchase of vehicles with low CO_2 emissions and for diesel vehicles, standard equipped with a particulate filter (PM-filter). Vehicles with CO_2 levels between 105 and 115 grammes per kilometre receive a reduction of 3% of their purchase price, with a maximum amount of 810 Euro (indexed amount in 2008). Vehicles with CO_2 levels lower than 105 grammes per kilometre receive a reduction of 15%, with a maximum amount of 4350 Euro (indexed amount in 2008). A reduction of 200 Euro can be obtained when purchasing a diesel vehicle, standard equipped with a PM-filter and with a CO_2 level lower than 130 grammes per kilometre. This reduction does not apply to diesel vehicles, retrofitted with a PM-filter. In 2008, these reductions could be offered to no more than 43.626 vehicles, which is a small amount compared to the 535.947 newly registrered vehicles in that year [6]. This supports the need for a more appropriate policy approach stimulating the purchase and use of clean vehicles. Ownership taxes consist of an annual circulation tax and a compensating circulation tax for LPG and CNG vehicles. The yearly circulation tax is currently based on the power of the vehicle, expressed in fiscal horsepower and cilindre capacity. Finally, user taxes refer to the VAT and excises applied on fuels. LPG, CNG and electric vehicles are exempted from excises [7].

4 Life cycle cost analysis

The private consumer costs per year and per kilometre are displayed in figures 1, 2 and 3. It seems that there is a large dispersal of the results. A vehicle can have a yearly cost from 3.000 up to 20.000 €, with a cost per kilometre that varies from 0,20 € (supermini) up to 1,4 € (exclusive car). The prices of diesel and petrol have been rising increasingly during the last couple of years and make environmental friendly vehicles more and more attractive. The retrofitted LPG cars have for example lower private costs compared to their petroleum equivalent. Although these vehicles are confronted with additional conversion costs, a higher depreciation rate, a compensating circulation tax and higher costs for technical control, they benefit from lower fuel prices at the filling station thanks to the low production cost of LPG and the exemption of excises. The battery-electric Peugeot 106 has a less attractive cost relative to the other cars of the supermini segment. This car is faced with a high purchase price (due to small-scale production) and high battery costs. Without any battery replacements, this car would have a very low variable cost of 0,21 € per kilometre. This could be the case when lithium batteries, designed to last the vehicle lifetime, will be introduced [8].

A general look at figures 1, 2 and 3 discloses that in most of the cases, the diesel version is more cost-efficient than its petroleum equivalent. Although diesel cars are often confronted with a higher purchase price, they benefit from lower fuel costs thanks to a lower fuel consumption (-20 to 30%) and lower excises (-50%). This cost-effectiveness and the better performance over time resulted in a so-called “dieselification” of the Belgian car park. Over the period 1970-2007, the amount of diesel cars duplicated whilst the number of petrol cars decreased with 15%. In 2007, petrol cars represented only 23% of the newly registered cars, compared to 77% diesel cars [9]. An important drawback of this evolution is the increasing amount of PM in the air. A PM-filter can counterbalance this important negative environmental effect but the question is whether these cars with filters will be as cost-efficient as their equivalents without filters. Figures 1, 2 and 3 reveal that this is only the case for two cars: the Ford Galaxy and the Mercedes M type which have their PM-filters standard equipped. In all other

cases, the PM-filter is an extra option on top of the purchase price. The Belgian governmental support of 200 € is not enough to compensate this extra cost. As a result, the PM- filter will only convince consumers which are aware of the environmental problem and willing to pay an additional cost for it.

In figure 2, several cars with blends of bio-ethanol are presented. These cars turn out to be the most expensive ones, in the segment of large family cars as well as in the monovolume segment. The high private consumer costs are first of all the result of higher purchase prices. Most cars are not available as a biofuel compatible car, so conversion costs must be taken into account. Conversion costs typically vary between 0 and 1.000 €, depending on the car manufacturers. High blends such as E20 and E85 are usually faced with conversion costs up to 1.000 € as they require technical adaptations of the engine. Low blends like E5 and E10 are still compatible for all vehicle engines so no additional conversion costs need to be taken into account. A second reason for the high private costs are the higher fuel production costs as they depend on several parameters such as raw materials, capital cost, intermediary processing and logistics. The higher the percentage of biofuels in the blend, the higher the total fuel costs will be. Biofuels could become more cost-efficient if a reduction of excises proportional to the biofuel content would be introduced. The Volvo V50 E85 would get for example an excise reduction of 85%, resulting in a cost per kilometre of 0,47 € instead of 0,52 €. Finally, total fuel costs are also higher because of the supplementary fuel consumption due to the lower energetic density of the fuel. Low blends require no extra fuel consumption, whereas the fuel consumption of E20 and E85 increases with respectively 4% and 30%.

The LCC analysis includes four types of hybrid cars, namely the Honda Civic, Toyota Prius, Lexus LS and Lexus RX. The Toyota Prius benefits from a large governmental CO_2 support which makes it a very cost-efficient vehicle for the end-user. Real sales data show indeed that this support is vital for its encouragement. With more than 6.500 units sold in 2008, the Toyota Prius is ranked at the 22nd position of best selling cars in Belgium [10]. This market success can be attributed to the combination of the governmental support and its great fuel efficiency which makes it a rational decision to purchase this car. Despite this governmental support, there are still clean vehicles such as the hybrid Honda Civic which remain too expensive for the end-user.

The LCC analysis relies on several parameters, many of which have uncertainties. In order to verify the sensitiveness of the end results to these uncertainties, a sensitivity analysis has been performed for the key parameters: yearly vehicle mileage, years of car use and fuel prices. This analysis showed that the uncertainties had no influence on the outcome of the model.

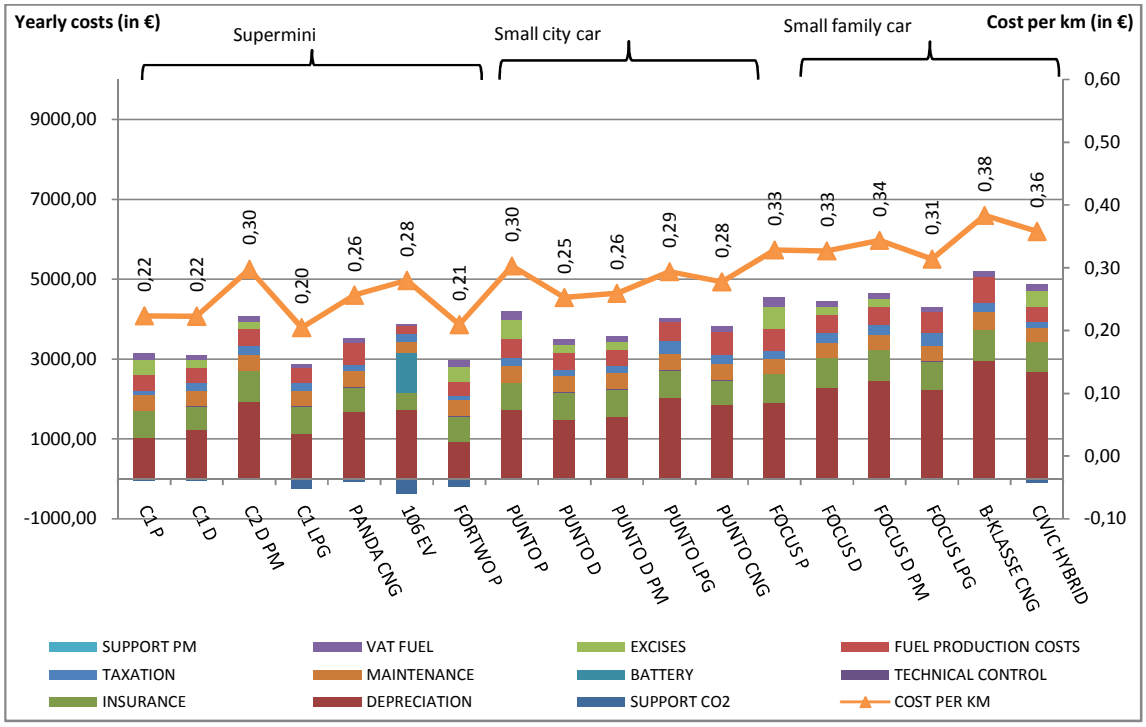

Figure 1: Private consumer costs for supermini, small city car and small family car

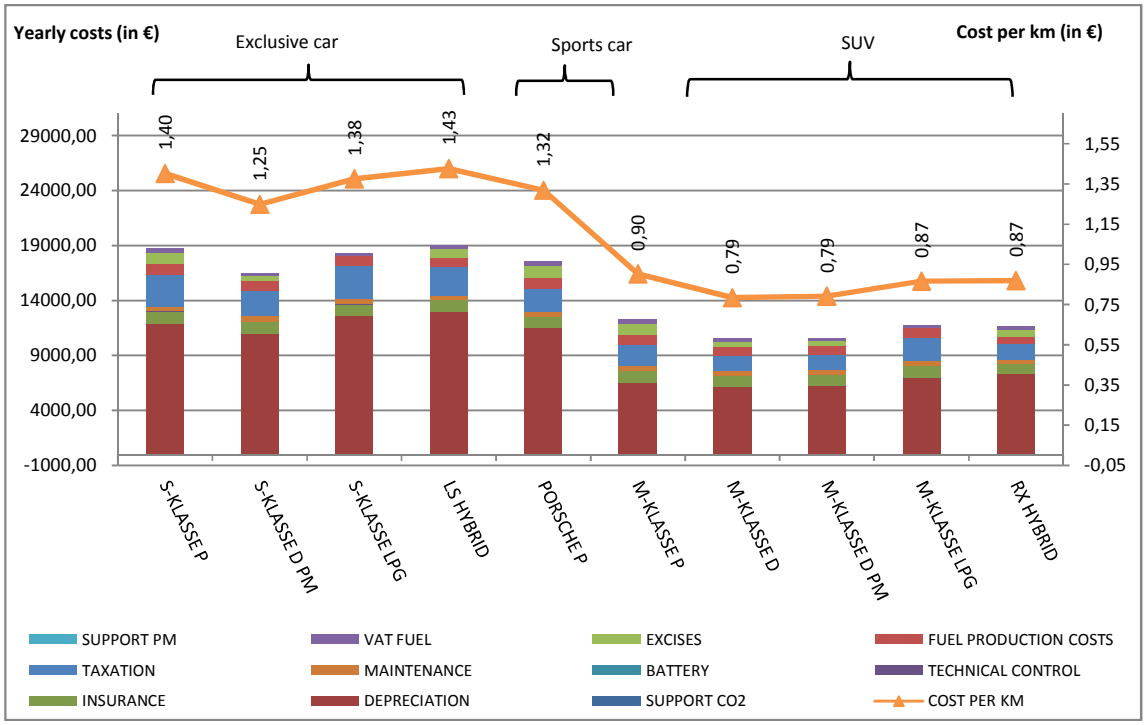

Figure 2: Private consumer costs for big family car, small monovolume and monovolume

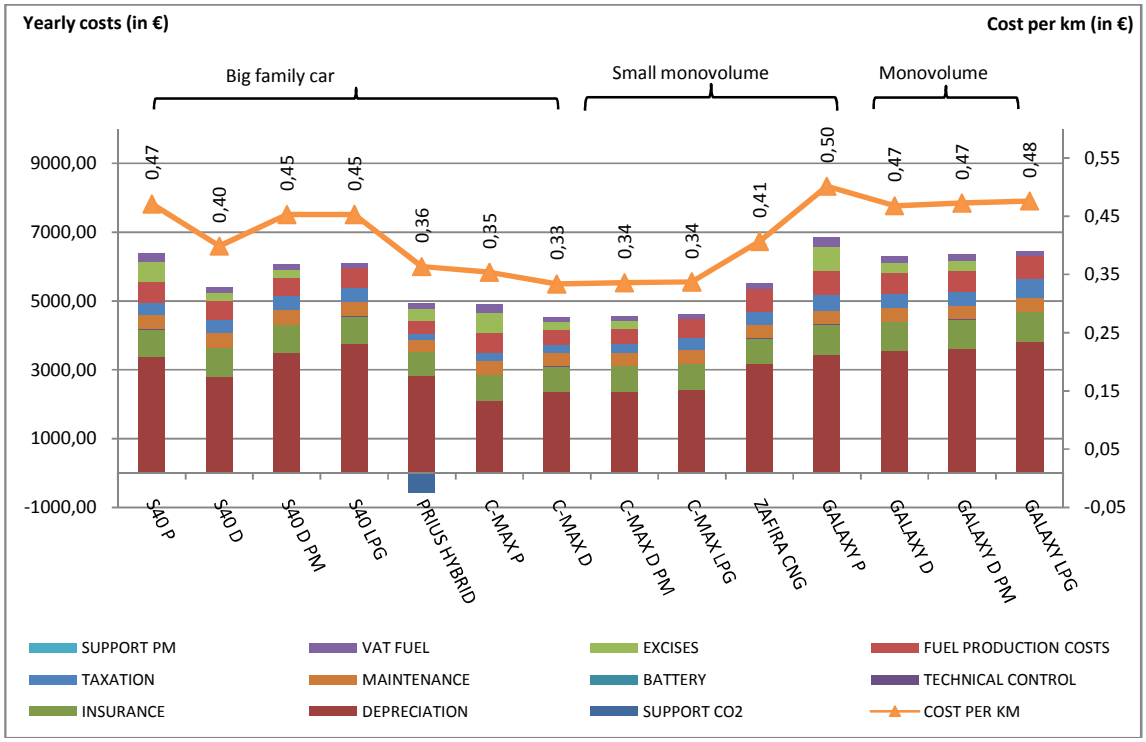

Figure 3: Private consumer costs for exclusive car, sports car and SUV

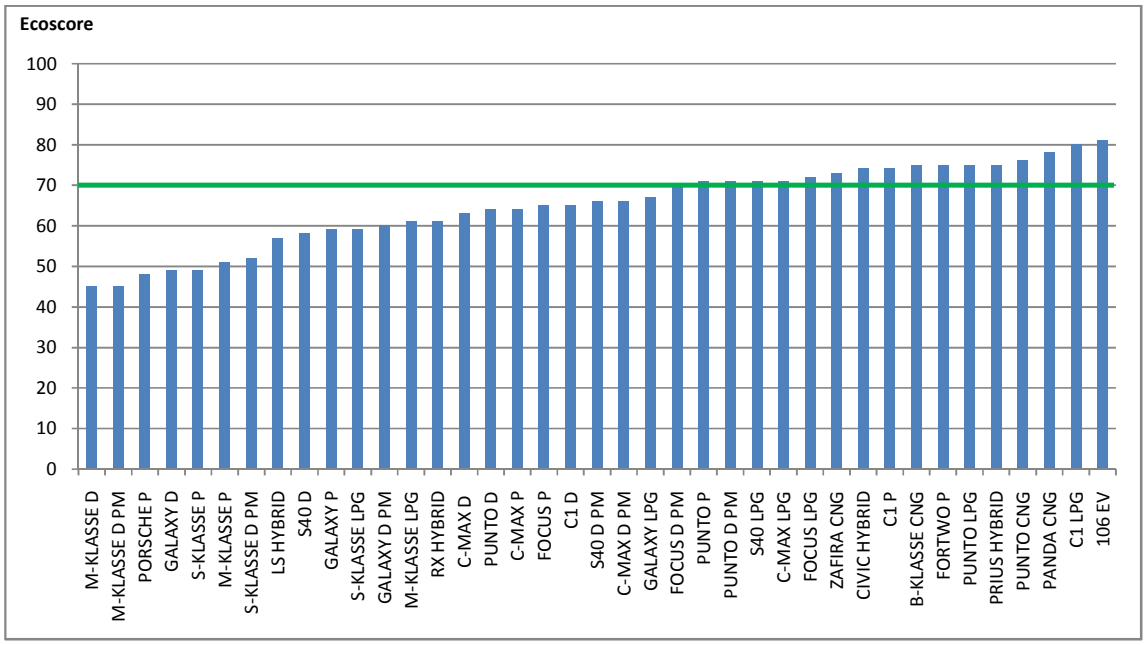

Figure 4: Ecoscore of light duty vehicles with different fuels/drive trains [11]

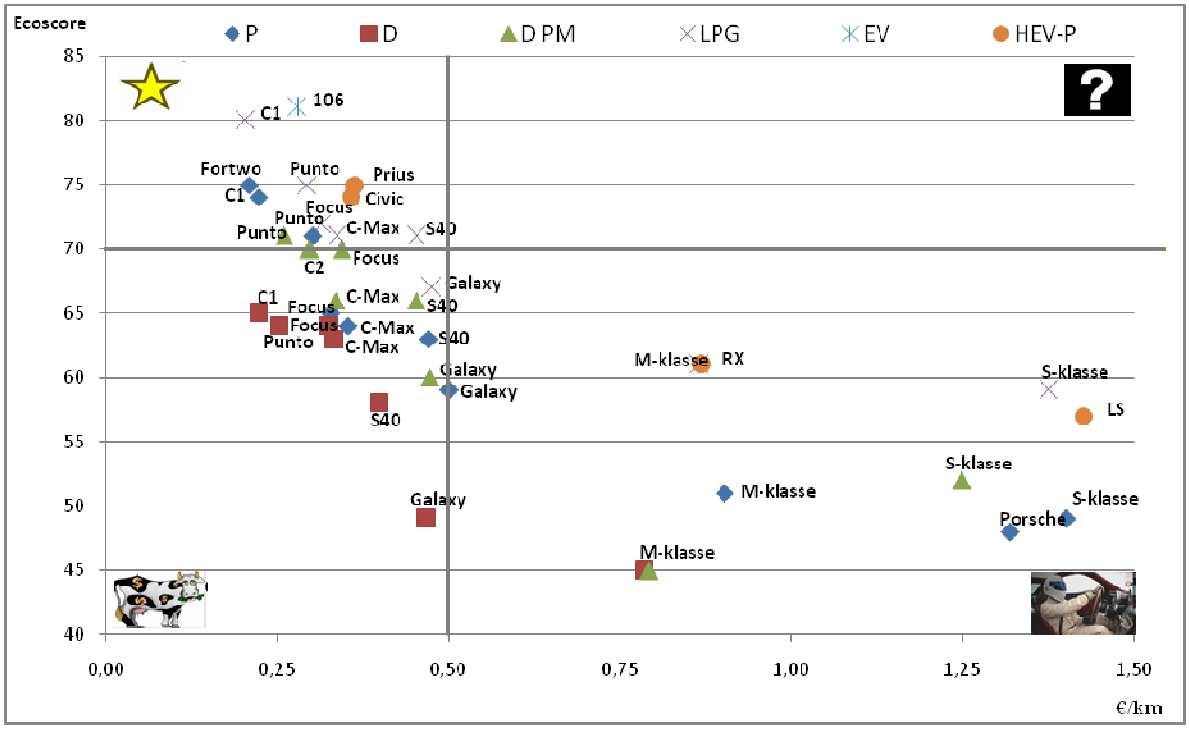

Figure 5: Balance cost-efficiency and environmental friendliness

5 Life cycle cost – Ecososcore matrix

By means of a LCC-Ecoscore matrix, the balance between the cost-efficiency and environmental performance of each car can be assessed and market opportunities discovered. The environmental performance of each car has been measured by way of the Ecoscore methodology which has been developed by the Vrije Universiteit Brussel (VUB-ETEC), Université Libre de Bruxelles (ULB) and the Flemish Institute for Technological Research (VITO). This method makes it possible to calculate an environmental score for every individual car, ranging from 0 (infinitely polluting) to 100 (emission free and silent). Several damage categories are taken into account: climate change, air quality depletion (health impairing effects and effects on ecosystems) and noise pollution. The Ecoscore is based on a well-to-wheel analysis, which means that besides tailpipe emissions, also the air pollution caused by the production and distribution of the fuel is taken into account. Emissions resulting from the vehicle assembly and from the production of its constituting elements are not taken into account. Nor are the maintenance phase and recycling phases of end-of - life vehicles. Analyses have shown that the emissions due to the using phase of the car are decisive compared to those of the production and end-of-life phases of the car [12]. The Ecoscore allows comparing different fuel (petrol, diesel, LPG, CNG, bio-fuels etc.) and drive train technologies (internal combustion engines, hybrid electric drive trains, battery electric drive trains etc.) based on their environmental performance. The environmental evaluation is being done according by a sequence of five steps, similar to those used in a standardised Life Cycle Assessment (LCA): inventory, classification, characterisation, normalisation and weighting. In the first step direct emissions (CO, HC, NO_x, PM, CO_2, SO_2, N_2O, CH_4) related to the use of the car and indirect emissions (CO, NMHC, NO_x, PM, CO_2, SO_2, N_2O, CH_4) related to the production and distribution of the fuel are collected. Once the total impact of these emissions is calculated, their contribution to the different damage categories (climate change, air quality depletion and noise) is analysed in the classification and characterisation step. The contribution of greenhouse gases is calculated using global warming potentials (GWP), whereas the contribution of air pollution is expressed in €/kilogram and noise pollution in dB(A), a decibel scale with A-weighting to take the sensitivity of human hearing into account. In

the fourth step, normalisation, the relative severity of the evaluated damages of each damage category is quantified based on a specific reference value. The reference point is the damage associated with a theoretical passenger vehicle of which the emission levels correspond with the EURO IV emission target level, a CO_2 emission level of 120 gramme/kilometre and a noise level of 70 dB(A). In a final step, the normalised damages are weighted before they can be added into the total environmental impact (TI). These weighting factors reflect policy priorities and decision makers' opinions. To obtain results situated between 0 and 100, where 100 represents a perfectly clean and totally silent vehicle, the TI is rescaled to the final Ecoscore indicator. The reference value for an environmental friendly vehicle corresponds with an Ecoscore of 70. Figure 4 shows the individual Ecoscores of several EURO 4 cars with different fuels (LPG, CNG, petrol, diesel) and drive train technologies (EV, HEV). It can be noticed that a EURO 4 Ford C-Max Diesel has for example a lower Ecoscore (63) than the EURO 4 Ford C-Max Diesel with PM-filter (66). Moreover, very favourable Ecoscores can be observed for the Peugeot 106 electric (85) and for LPG and CNG vehicles.

Figure 5 displays the balance between the cost and environmental friendliness as an adapted Growth-Share Matrix [13]. On the X-axis, the LCC is shown, whereas the Y-axis presents the Ecoscore. The matrix shows four quadrants. The first quadrant, the stars, are characterized by cars with a high environmental performance (Ecoscore > 70) and a high cost efficiency (< 0.50 €/km). As a result, cars in this segment will be able to support the transition towards a more environmental friendly fleet. Stars are mainly represented by superminis and small city cars. In order to appropriately assess the LCC-Ecoscore balance, one needs to compare each car with a comparable car from the same segment. The electric Peugeot 106 has for example a very attractive Ecoscore (81), but is more expensive (0,28 €/km) than its petroleum (0,22 €/km) and its diesel (0,22 €/km) equivalent. The stars also include big family cars (Toyota Prius and Volvo S40 LPG) and a small monovolume (Ford C-Max LPG) demonstrating that the environmental friendly version of a larger car (HEV, LPG etc.) is also able to become a star. The second quadrant, the cash cows, contains cars which are not environment friendly (Ecoscore < 70), but cost-efficient (< 0,50 €/km). They are called cash cows as these cars typically generate cash and are "milked" continuously with as little investment as possible. Not surprisingly, mainly diesel cars are situated in this quadrant. Thanks to their cost-efficiency and better performance over time, the Belgian market share of diesel cars duplicated over the period 1970-2007, representing real cash cows. Cash cows can become stars when putting efforts to make these cars more environmental friendly. One of the efforts that proofs to be effective is the standard equipment of a PM-filter, as illustrated by the Ford Punto and Ford Focus. Retrofitting cars with a LPG installation or by hybridisation would even be better. The exclusive cars, sports cars and SUVs are situated in the third quadrant, the so-called 'top-gear' cars. 'Top-gear' cars typically have a lower market share as they are more exclusive and expensive (> 50 €/km) and they are not at all environmental friendly (Ecoscore < 70). Although environmental friendly technologies (hybridisation, LPG, etc.) of these cars would increase their environmental performance, the question remains (fourth quadrant) if there is room for expensive exclusive cars (> 50 €/km), which are environmental friendly (Ecoscore > 70). This appears to be a rather difficult exercise as expensive cars are mainly more heavy cars and hence consume more fuel resulting in a reduction of the Ecoscore.

6 Tax impact analysis

6.1 Current fiscal system

By comparing the taxes with the external costs, it can be assessed whether the current Belgian fiscal system is promoting environmental friendly vehicles. External costs are the additional costs that car drivers impose on the society without having to bear these costs themselves [14]. In the literature, a distinction is made within environmental, accident and congestion costs [15]. These costs have been included in the external cost calculation as it provides an insight in the total real costs associated with the use of vehicles. The environmental costs have been calculated by means of a monetarisation of the environmental parameters, provided by the Ecoscore. The monetary valuation of greenhouse gases and noise pollution has been provided by [16], whereas the monetary valuation of air pollutants stems from [17], with updated values as described in [18] and [19]. In these calculations, a weighted average of urban (25%) and rural (75%) external costs was

used, referring to the national split between urban and rural mileage for light duty vehicles in Belgium [20]. The external congestion and accident costs are based on [16]. As there are no statistical data available for individual cars, it was not possible to make a distinction in accident and congestion costs according to the different vehicle types. The monetary values of [16] have also been weighted according to national split between urban (25%) and rural vehicle mileage (75%) of light duty vehicles in Belgium. The total external costs are calculated in three steps. First, the environmental, congestion and accident costs are calculated, taking into account a vehicle lifespan of 7 years and an annual vehicle mileage of 15.000 kilometres. Second, the present value of these external costs is measured by means of a discount rate. The discounting of external costs is the subject of considerable debate. With a higher discount rate, more importance is given to the near-present, while of discount rate of 0% gives an equal importance to the external effects of today and tomorrow [21]. Discount rates for external costs typically range from 0% to 5%, with 1% and 3% as most frequently used values. In the external cost calculation, sensitivity analysis has been performed to test the robustness of the outcomes at discount rates of 1%, 3% and 5%. This analysis showed that the different discount rates had no impact on the relative outcomes of the external cost calculation. Finally, the present value is divided by the vehicle lifetime to produce the external costs on a yearly basis. These total external costs can be compared with the total taxes on an annual basis. The annual taxes are based on a vehicle lifespan of 7 years and an annual vehicle mileage of 15.000 kilometres. They comprise the VAT of 21%, the vehicle registration tax, the circulation tax, the VAT on the batteries (in case of an EV), and the excises and VAT on the fuel minus the governmental support for low CO_2 emissions and the standard equipment of a PM-filter. An overview of the total taxes and total external costs on a yearly basis is given in figure 6.

Out of figure 6, the main distortions and strengths of the Belgian fiscal system can be identified serving as an input for the elaboration of a new fiscal system which deals with the fiscal distortions while preserving the strenghts. A first important distortion is related to the taxation of diesel cars. Diesel cars such as the Mercedes M-klasse, Ford Galaxy, Volvo S40 and Citroën C1 pay less yearly taxes, although have a lower Ecoscore relative to their petroleum equivalents. This lower taxation contributed to the increasing cost-efficiency of diesel vehicles over time resulting in a “dieselification” of the Belgian vehicle fleet. An important drawback of this evolution is the increasing amount of PM in the air. A PM-filter can counterbalance this important negative environmental effect. Diesel cars standard equipped with PM-filters like the Ford Galaxy, Volvo S40, Ford C-Max and Ford Focus are however faced with higher yearly taxes than their equivalent diesel versions without filters (second distortion). The governmental support turns out to be not effective in making these cars with filters attractive for potential car purchasers because of three reasons. First of all, the support of 200 Euro is not large enough to cover the extra costs associated with the equipment of a PM-filter. Secondly, several criteria need to be reached to get selected for this support (CO_2-level < 130 g/km and PM level < 5 mg/km). As a result, only small cars will be considered for the support, ignoring middle-sized and larger vehicles. Finally, the support is only granted for standard equipped PM-filters, and not for retrofitted diesel vehicles with PM-filters. Overall, the PM-filter will only convince consumers which are aware of the environmental problem and willing to pay an additional cost for it. A third distortion of the fiscal system is found in the taxation of biofuel cars. Higher contents of biofuels in blends are faced with higher taxes. The government has the possibility here in making these cars more attractive by adapting the excises relative to the content of biofuels in the blend. A final distortion is associated with the taxation of LPG cars. Some cars on LPG such as the Fiat Punto are more heavily taxed than their equivalents on petrol, despite their higher Ecoscores. The reason for this higher tax burden is the compensating circulation tax for LPG and CNG cars. This tax should be abolished in the new tax reform as to make these cars more cost-efficient and attractive. LPG and CNG vehicles benefit on the other hand from low fuel prices at the filling station thanks the exemption of excises and the low production costs of these fuels. This is one of the first strenghts of the current fiscal system. A second strenght is the governmental support for low CO_2 emitting cars. Real sales data clearly show that this support is vital for the encouragement of environmental friendly vehicles such as the Toyota Prius. Despite this governmental support, there are still clean vehicles such as the hybrid Honda Civic or the electric Peugeot 106 which are too expensive for

the end-user. This is mainly the result of their higher purchase prices (due to small-scale production) and battery costs. These cars could become more attractive when reforming the vehicle taxes in function of the Ecoscore.

6.2 New fiscal system

In Belgium, the Flemish, Walloon and Brussels Capital region are in charge of the vehicle taxation system related to passenger cars. Vehicle taxes are collected on a federal level, after which they are distributed to the three regions. Each region may in this respect individually change the tax basis for private persons. A tax reform in one region should however happen in agreement with the other regions to avoid some perverted effects such as the shift of vehicle registrations from one region to another. When affecting company cars, a coorperation agreement is necessary to reform vehicle taxes. The three regions are presently considering different policy measures to promote environmental friendly vehicles. The Walloon region introduced for example a CO_2 bonus/malus system where vehicles with CO_2 emissions > 195 gr/km are punished with an additional circulation tax, while vehicles with lower CO_2 levels are rewarded with a subsidy. The Brussels and Flemish region are on the other hand elaborating a tax reform based on the Ecoscore. The Flemish region even has officially expressed its intention to modify the vehicle registration tax and annual circulation tax in function of the Ecoscore. It is of particular interest whether such a Flemish tax reform would evoke a shift in the vehicle fleet to a more ecological composition. A first proposal of a Flemish reform comes down to a more heavily tax burden for polluting cars (low Ecoscore), while environmental friendly cars (Ecoscore $\geq$ 70) will be rewarded with less taxes compared to the current fiscal system. The use of the Ecoscore as basis for a new fiscal system has some clear advantages compared to the use of for instance the EURO standard or the CO_2 emissions of a vehicle. The Ecoscore allows not only to mutually compare different vehicle technologies, but also to take into account the range on the emissions of vehicles from the same EURO standard.

Figure 7 makes a comparison of the total annual taxes in the current and new fiscal system. The new taxes comprise the adapted registration tax, the adapted circulation tax and an abolishment of the compensating tax for LPG and CNG vehicles, while keeping all other taxes (VAT on purchase price, VAT and excises on fuel, VAT on batteries) and subsidies (CO_2 support en support for diesel vehicles with PM-filters) unchanged. As such, the total yearly tax burden in the new fiscal system can be assessed, and the extent in which a tax reform can contribute to turning the vehicle fleet into a more environmental friendly one.

It appears that this new fiscal system can indeed contribute to a higher yearly tax burden of diesel vehicles, conform their worse environmental performance. This is for example the case for the Mercedes M-klasse, Ford Galaxy and Fiat Punto. However, the tax burden of the Mercedes M-klasse (Ecoscore 45) will still be relatively lower than the tax burden of the Porsche petrol (Ecoscore 48). This is totally due to the higher excises on petrol compared to diesel in the Belgian fiscal system. The tax reform also stimulates the cost-efficiency of vehicles with PM-filters as demonstrated by the Ford Galaxy, Volvo S40, Ford C-Max, Ford Focus and Fiat Punto which become more attractive than their equivalents without filters. Thanks to the tax reform, the purchase of LPG and CNG cars will also be stimulated as the additional circulation tax will be abolished, while keeping the current exemption of excises on these fuels. The tax reform also manages to lower the yearly tax burden of some environmental friendly vehicles which are at present too expensive such as the Peugeot 106. The yearly tax burden of the Peugeot 106 (Ecoscore 81) will nevertheless remain relatively higher than the one of the Citroën C1 LPG (Ecoscore 80) as it is confronted with additional taxes (VAT) on its batteries. Overall, this tax reform is perceived as an effective tool to bring the yearly taxes more in accordance with the environmental performance of the vehicles. As such, clean vehicles will be stimulated, whereas the purchase of polluting vehicles will be discouraged.

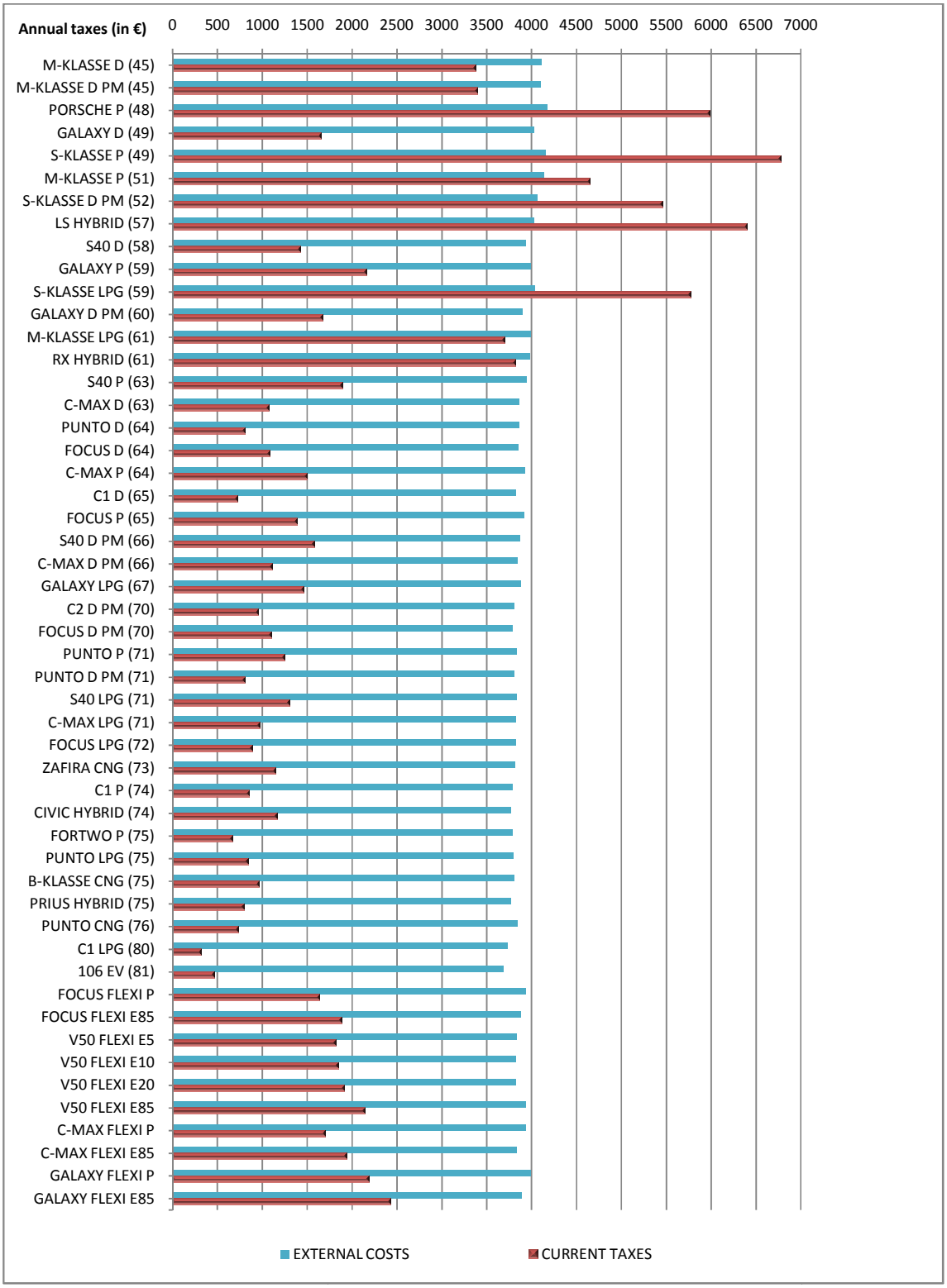

Figure 6: Yearly taxes, yearly external costs and the Ecoscore

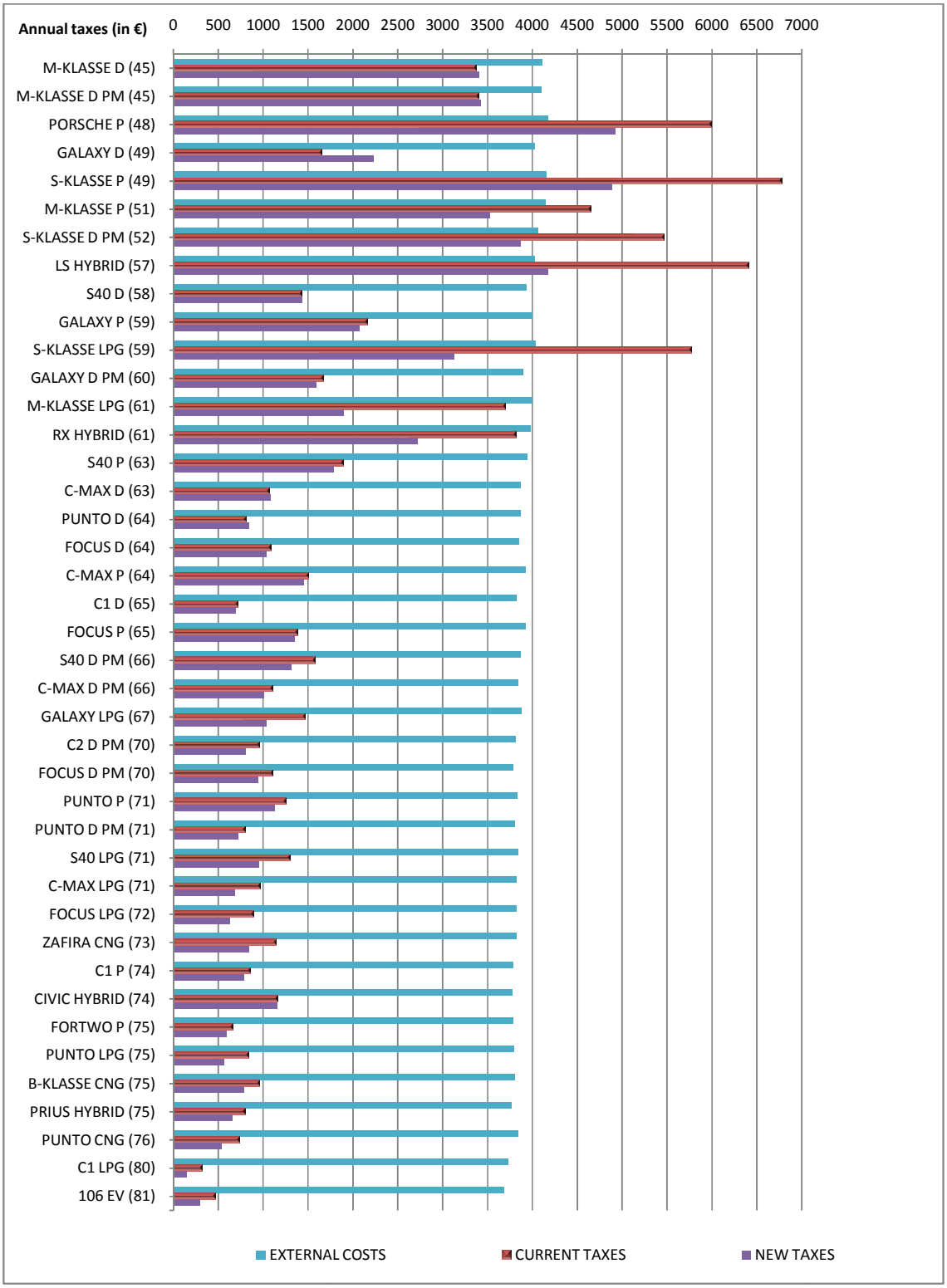

Figure 7: Current taxes, new taxes and external costs on a yearly basis

7 Conclusion

In order to investigate whether the current Belgian fiscal system is promoting environmental friendly vehicles, a life cycle cost model was first of all developed to compare the cost-efficiency of different vehicle technologies. By adding an environmental score (Ecoscore) to each individual car, a classification could be made according to the cost-efficiency and environmental performance. "Stars", characterized by cars with a high environmental performance (Ecoscore > 70) and a high cost-effectiveness (< 0,50 €/km), are mainly represented by supermini's, small city cars and environmental friendly versions (LPG, HEV) of larger cars. Cars in this segment will be able to support the transition towards a more environmental friendly fleet. "Cash cows", defined by a low environmental performance (Ecoscore < 70) but a great cost-efficiency (< 0,50 €/km), consist mainly of diesel cars. These cash cows can become stars when putting efforts to make these cars more environmental friendly such as the standard equipment of a PM-filter. Exclusive cars, sports cars and SUVs, characterized by a poor environmental performance (Ecoscore < 70) and a very low cost-efficiency (> 0,50 €/km), find themselves in the "Top Gear" segment. Although environmental friendly technologies (hybridisation, LPG etc.) of these cars would increase their environmental performance, the question remains if there is room for expensive exclusive cars (> 0,50 €/km) which are environmental friendly (Ecoscore > 70). Secondly, by comparing the taxes with the external costs (environmental, accident and congestion costs), it was examined whether the Belgian fiscal system stimulates the purchase and use of environmental friendly vehicles. The following fiscal strenghts and distortions have been identified. Private consumer costs of LPG cars are lower compared to their petroleum equivalents thanks to the exemption of excises on these fuels (strength 1). Nevertheless, these cars are still confronted with an additional circulation tax which causes a heavy yearly tax burden (distortion 1). Electric cars and cars with blends of bio-ethanol seem not so cost-efficient for the end-users. Reasons for the high costs of electric cars are the high financial costs and high battery costs. Bio-ethanol cars are, on the other hand, faced with high fuel costs due to a combination of a high ex-refinery price, a higher fuel consumption and high excises on biofuels (distortion 2). The attractiveness of hybrid vehicles mainly depends on their financial costs as their low fuel consumption makes it a very cost-efficient car for the end users. The governmental support for low CO_2 emitting vehicles is in this respect a great effort to increase their attractiveness for the larger public (strength 2). Diesel cars are very cost efficient for the end user thanks to their lower fuel consumption (-20 to 30%) and excises (-50%) relative to their petroleum counterparts. Diesel cars are however not attractive for the society as they pay less taxes whilst they are more polluting in terms of PM than petrol cars (distortion 3). As a result of this lower taxation, there is an increasing number of diesel cars in the Belgian car park with an rising negative impact on the environment. Diesel cars, standard equipped with a PM-filter, are however not a cost-efficient option as they are more expensive than their equivalents without filter. The governmental support appears here not effective in making these cars attractive for potential car purchasers (distortion 4). Finally, a tax reform based on the Ecoscore, has been proposed tackling the main distortions of the Belgian fiscal system meanwhile encouraging the cost-efficiency of environmental friendly vehicles. It has been found that such a fiscal system may, on the long term, evoke a shift in the composition of the Belgian car fleet towards a more environmental friendly one as clean vehicles will be stimulated, whereas the purchase of polluting vehicles will be discouraged.

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Authors

Laurence Turcksin received the degree of International Economics at the Universiteit Gent, after which she started working as a PhD student at the department MOSI-Transport and Logistics of the Vrije Universiteit Brussel on the development of a purchase and usage model for cars and especially environmentally friendly vehicles.

Cathy Macharis obtained her Phd in Economic Sciences at the Vrije Universiteit Brussel. She is now full-time lecturer at the Vrije Universiteit Brussel and leads the MOSI-transport and logistics research team. This group is specialized in the socio-economic evaluation of transport projects and policy measures.

Joeri Van Mierlo obtained his PhD in Engineering Sciences from the Vrije Universiteit Brussel. Joeri is now a full-time lecturer at this university, where he leads the ETEC research team on transport technology. His research interests include vehicle and drive train simulation, as well as the environmental impact of transportation.

Nele Sergeant received the degree of Bio-engineer in biotechnology at the Vrije Universiteit Brussel in 2003, after which she specialized in environmental science and technology and the Katholieke Universiteit Leuven. She started working as a PhD student at the Electrotechnical engineering department (ETEC) of the Vrije Universiteit Brussel on the Ecoscore methodology and the development of an LCA for conventional and alternative vehicles.