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Modeling the effects of environmentally differentiated distance-based car-use charges in the Netherlands

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ABSTRACT

This paper uses the automobile market model Dynamo to assess the effects of replacing car purchase and road taxes with CO_2-differentiated distance-based user charges in the Netherlands. The effects of this replacement on vehicle size and the composition of the car fleet are estimated, as are the effects on emissions and mileage. We conclude that distance-based charging schemes can reduce CO_2 emissions and other traffic-related pollutants but can also have unintended impacts on the size, composition and environmental performance of the national car fleet (e.g., car ownership increases, fuel efficiency is reduced and emissions per kilometer driven increases). These unintended effects occur because households react more strongly to one-time fixed costs than to recurring variable costs and because car costs are reduced for households with relatively low car usage. Environmentally differentiated distance-based charges can reduce these effects, but only partially.

1. Introduction

Many countries, and particularly within Europe, have a two-part tax structure for passenger cars to cover the cost of constructing and maintaining roads and to reduce transport-related costs to society, including congestion, pollution and accidents. Governments tax car ownership and use separately, but the systems are only partially related to infrastructure and social costs. For example, in the Netherlands, a 55% of car-related taxes are related to car ownership, while the remainder related to vehicle use. Optimal tax theory suggests that there is no explicit role for annual ownership taxes in correcting externalities. In practice, however, policy-makers face restrictions, including political and public acceptability, regarding the variable pricing instruments that they can use to correct the external costs of congestion and pollution. Moreover, fixed ownership taxes are also used, albeit indirectly, to offset externalities. For example, in the Netherlands, current car purchase taxes are differentiated by fuel type, CO_2 emission and emission standard to stimulate consumers to purchase fuel-efficient and environmentally friendly cars.

The paper examines the extent a distance-based user charge should be based upon the environmental effects of the car's usage, and compares the effects of a higher usage charge for more polluting cars with flat fee-based schemes. These effects are assessed in terms of vehicle kilometers driven, size and composition of the car fleet, emissions and government revenue. To achieve this, a dynamic car market model is used that takes into account the effects of type-specific user charges on the use of the car as well as on the size and composition of the car fleet.

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2. Differentiation in car taxation schemes

Pricing instruments have been considered in several countries, under the general heading of "road user charging". In the US, experiments with "mileage fees" have been driven primarily by budget constraints and the need to raise revenues to maintain the road system. Distance-based charging for trucks exists in Germany, Austria, Switzerland and the Czech Republic, and other countries are considering their introduction. The Dutch Parliament, for example, approved a national distance-based charging system for passenger and freight vehicles in 2008, but this plan was cancelled in 2010 after general elections following the fall of government (Geurs et al., 2010).

The distance-based charging scheme considered by the Dutch government became rather complicated to satisfy a number of political preconditions; vehicle tax revenues should not decrease, the fuel mix of the car fleet should not shift substantially, car emissions should decrease substantially, and perturbations in the second-hand market should be minimal. In addition, new tariffs would change annually based on average CO_2 emissions in the car fleet, even though as more fuel-efficient cars are purchased, tax revenue would fall, thereby violating one of the conditions. Furthermore, the original intention was for the tariff to vary with time and place, with higher charges levied during peak hours and on busier roads. This would require each vehicle to be fitted with an "on-board unit" to monitor when and where people drove. Despite the high costs of a national GPS-based road pricing scheme system (some €2–3 billion for set up and €0.5–1.1 billion annually thereafter), cost-benefit alternatives showed economic benefits of about €0.8–1 billion/year (Besseling et al., 2008).

3. The Dynamo car market model

To assess the effects of replacing environmentally differentiated distance-based car user charges with fixed car costs, we use a framework that includes disaggregate demand and supply models sensitivity to type-specific car taxes, the durability of the vehicles including aging and scrapping, changes in the size and characteristics of the fleet, including the introduction of new cars and the import and export of used cars into the fleet, and market prices. This "Dynamo" (Dynamic automobile market model was developed specifically to assess the effects of environmentally differentiated road user taxes; Fig. 1 shows the main elements.

The starting point in Dynamo is the base matrix, which describes the aggregate car ownership of various household types. Household types are defined using a combination of household size, number of employed persons, the age of the oldest resident, and disposable net household income. Combining these characteristics in the model generates 71 household types; the H matrix. In addition, 120 vehicle types can be defined by combining the age of the car (five classes), its fuel type (three classes), its weight (four classes) and ownership (private or company-owned). Household types, that are exogenous effects on the choice of car types, combined with car types yields the base matrix; the automobile household (AH) matrix. This matrix, of 8250 cells, describes car ownership in a given year for each household type.

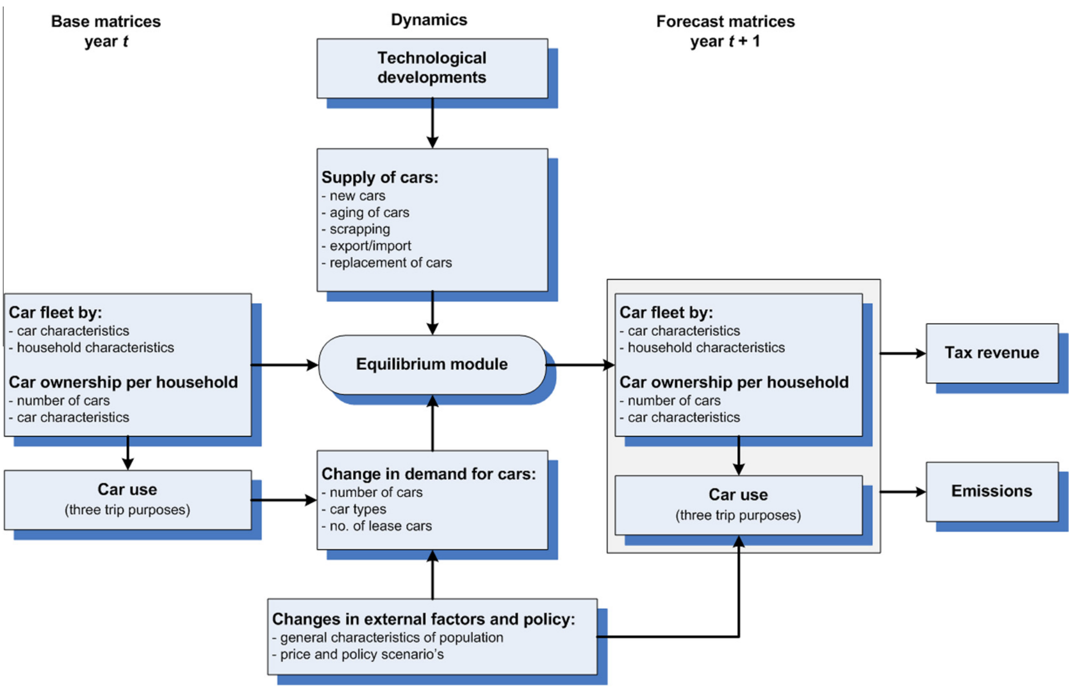

Fig. 1. Main characteristics of Dynamo.

To assess changes in car ownership, several modules are deployed; the main ones being.

- D(Household). This module determines the change in the number of households per household type. This is an exogenous variable in the car ownership model.
- D(Car use). This module determines the number of kilometers driven for each purpose (commuting, business, other), the average number of kilometers driven per household and the number of kilometers driven per car type. Developments or policies that can affect the variable costs of car ownership are incorporated into the model via this module.
- Scrapping and accidents. The probability that the car will not be scrapped and will therefore remain in the active car fleet for another year is determined per car type. An additional 0.108% of all cars, randomly distributed among all vehicle types, are removed from the car fleet annually as a result of accidents. This figure is based on vehicle registration statistics.
- ImExport. Dynamo assumes a constant sum of imported and exported cars for each car type. This assumption can be a simplification because import and export rates depend on such things as the price differential between the Netherlands and other countries and it is assumed that this difference is −1.15% for each vehicle type in the active car fleet.
- HHNumber. This module determines the number of cars in each household type and is subdivided into 0, 1, 2, or more than 2 cars.
- DHHLease. This module determines the number of leased/company-owned cars for each household type. In this version, this number is determined outside of the car ownership model. Furhermore, the distribution of new leased/company-owned cars is determined.
- Type choice. This module determines the distribution of privately owned vehicle types for each household type.
- Environment. This determines CO_2, CO, NOx, VOC and PM10emissions produced by the car fleet using emission factors obtained from the Netherlands Environmental Assessment Agency.
- CO_2 module. This disaggregates the 120 vehicle types into 28 emission categories using a disaggregate logit with the same variables as the DHHLease and Type choice modules. This gives 3360 car types for which input values can be specified and an output is determined. This detail is needed because under the Dutch car taxation system, the taxation is increasingly based on CO_2 emissions. CO_2-based charges can also differ for each CO_2 class. This module is, however, based on original car types, and thus the fixed and variable costs of the 3360 car types are aggregated into 120 weighted according to their number in each CO_2 class.

The HHNumber module generates the demand for cars, and Type choice and DHHLease the desired distribution across the various vehicles types, within period t. The existing car fleet, which has become 1 year older from period $t-1$ through t and from which some cars will be scrapped or subject to export/importing, defines the supply of cars in year t, in which Dynamo assumes new vehicles are available without any restrictions.

In general, the supply and demand for a car type is not in equilibrium, and so the EMOD module adjusts prices of second-hand car prices to obtain equilibrium. Dynamo determines the price in the car market that matches the demand and supply of cars. It is assumed there is a delayed reaction to any price change; e.g. a person who wants to purchase a car in year t will tend in part to base his/her decision on prices in the previous year. To determine coefficients, time-related data series covering 1998 through 2003 are used, and that combination of coefficients yielding the best forecasts is selected. The result of this is that the price for t counts for 0.1, that for $t-1$ for 0.8, and that for $t-2$ for 0.1 again.

The HHNumber, Type choice and EMOD modules are iterated several times over 12 months with the result that changes in price in the second-hand market have an effect on the size and composition of the car fleet in a particular year. In practice, this effect becomes noticeable in the same year rather than a year later. The algorithm produces a set of 48 equilibrium prices for second-hand cars; prices of new cars are considered to be exogenous. This provides the vector of 60 car prices within year t. A new "market" price for year t is determined based on both these equilibrium prices and prices from the previous periods.

Using a nested logit model, with the top nest relating to decisions of whether to have a car, and the bottom to the number of cars owned, HHNumber estimates the number of cars (one, two, or more than two) that are owned by each household type at year t Summing these then provides the demand for vehicles. In the base matrix, the household type is used to assess the effects of household characteristics, but other variables are added. "Car price index" is a measure of the change in the average purchase price of vehicles relative to change in the general price level. Furthermore, variable costs of car ownership are included in the model; a change in the variable costs of ownership affect the kilometers demanded and, thus affect car ownership. The logsum of type choice represents the most attractive car that people can choose. If car costs increase, owning one or more cars will become less attractive, resulting in a higher probability that a household will not own a car in the top nest.

The model is estimated in two rounds. The coefficients for the household characteristics and the logsum associated with the choice between zero and one or more cars is initially estimated based on large pooled cross-sectional data from the Dutch National Travel Surveys between 1990 and 1998, with other parameters are estimated in the second round using the base matrix because the Dutch travel surveys provide no information regarding vehicle type, kilometers driven, or movements in vehicle prices. A linear logit model is estimated for the car ownership shares, using average kilometers and the logsum associated with the type as explanatory variables (Table 1).[1]

[1] Household variables that are not shown are the reference categories, all of which have zero values.

Table 1
Estimates for HHNumber.

Variable	Coefficient	|t-Value|
First round		
Top nest (>0 cars is reference)		
Logsum parameter bottom nest	0.100	37.8
0 cars, average income	−1.019	66.1
0 cars, high income	−1.583	89.2
0 cars, two person household	−1.474	112.7
0 cars, >two person household	−1.681	98.9
0 cars, 35–64	−0.862	57.4
0 cars, >64	−0.267	14.3
0 cars, 0 employed in household	0.727	50.6
0 cars, >1 employed in household	0.008	0.3
Pseudo R^2 = 0.436 N = 270,910		
Bottom nest (>1 car is reference)		
1 car, average income	−0.587	22.3
1 car, high income	−1.437	62.0
1 car, >2 person income	−0.845	55.3
1 car, 35–64	−0.179	7.2
1 car, >64	−0.231	6.0
1 car, 0 employed in household	−0.229	8.8
1 car, >1 employed in household	−0.352	23.1
R^2 = 0.530 N = 225,308		
Second round		
Variable (>1 car is reference)		
(α) Car price index	4.792	11.9
(β) Household kilometers	−0.145	97.3
(γ) Logsum type choice	−0.155	6.0
R^2 = 0.946 N = 34,454		

Note: based on (OVG, 1998).

With respect to parameters' signs in the first round, each is as expected. The probability of ownership increases with the attractiveness of the car (logsum refers to the alternative ">1" car), income, household size, age group and employment status. The second round of the model has a good fit, and the signs for the cost, mileage and attractiveness of the cars are also plausible. Constants were added for both the top and bottom nests for each household type; the model now reproduces the national statistics for the size of the car fleet in the base year.

The module Type choice models the choice of car type for privately owned cars. A multinomial logit model based on combined SP–RP data was used to estimate the type choice model. The available alternatives include the 60 car types that can be chosen by a private household.

The demand for private cars is estimated using data from a stated choice study conducted to estimate the effects of distance-based charge systems on car ownership and usage, and the composition of the car fleet in the Netherlands (MuConsult, 2002) Data from 562 new or second-hand private vehicle households regarding the type of car they owned (RP) or would purchase (SP) is used. A variable reflecting the number of vehicle models available for a particular car type is also included, because the car fleet consists of more models than the 60 types that are distinguished in the car ownership model. The more variations there are in a particular class, the more attractive that class becomes.

Estimates of the price variables are based on the combined SP–RP data set, with the other variables in Table 2 based only on RP data. Parameters are also estimated for the specific SP variables and the scale parameter to allow estimation of a combined SP–RP model. Only the variables that are used in the Type choice module are shown in Table 2. It shows that households prefer large new cars, a preference that increases with higher income, decreasing costs of purchasing and using cars, and when as the variety of models and options available increases. The same parameters are used to disaggregate car types into CO_2 classes.

The DHHLease module determines the size of the company-owned cars fleet, the costs of which are normally borne by employers, and the distribution of vehicle types. Because most company cars are purchased new, there are only twelve options. The data used to estimate the choice are mainly from the same SP-RP study of private consumers, with additional variables included to reflect the specific characteristics of the demand for company cars. For company car users, purchase price is not the main concern unless they wish to drive a vehicle that is more expensive than that offered by the employer. A specific variable for these private costs is used. Further, for income tax purposes, a company car user must add part of the value of the company car to their income; an adjustment is made to income to account for this. Table 3 gives the results of the model estimated using the variables used in the DHHLease module.

Dynamo contains a scrapping module to calculate the probability that a vehicle that is 10 years or older will be scrapped. Cars under 10 years of age have a small fixed probability of being scrapped (as observed in the 2003 statistics for cars that are

Table 2
Coefficients in the type choice module.

Variable	Coefficient	|t-Value|
Costs		
Ln(Purchase price)	−2.000	1.8
Variable costs (in thousands)	−0.587	3.1
Road tax (in thousands)	−0.683	12.8
Supply		
Ln(Size)	0.511	4.8
Weight class × income		
Low income: <951 kg	0.162	0.4
Low income: 951–1150 kg	−0.239	1.2
Low income: 1151–1350 kg	0.054	0.2
Low income: >1350 kg	0.346	–[a]
Average income: <951 kg	−1.353	3.7
Average income: 951–1150 kg	−0.147	0.8
Average income: 1151–1350 kg	0.666	4.0
Average income: >1350 kg	0.834	–[a]
High income: <951 kg	−1.477	3.7
High income: 951–1150 kg	−0.785	3.4
High income: 1151–1350 kg	0.600	2.8
High income: >1350 kg	1.663	–[a]
Age class cars		
New	1.298	2.4
1–2 years	0.239	0.7
3–5 years	0.177	2.0
6–10 years	−0.441	1.5
>10 years	−1.273	–[a]
Observations (resp. × choice sets)	RP: 562 × 1	SP: 1016 × 12
Alternatives in choice set	RP: 60	SP: 6
Model fit (Pseudo R^2)	0.056	

[a] Reference category.

scrapped). The probability of being scrapped was assessed using a multinomial logit function with the following utility functions:

$$\begin{cases} Utility_{scrapping} = C_{scrapping} \\ Utility_{no\,scrapping} = C_{no\,scrapping} + \alpha^{*}(residual\ value - subsidy) - \beta^{*} repairs + \varphi^{*} other \end{cases}$$

where α, β, and φ are parameters to be estimated and the C's are constants.

The constants $C_{scrapping}$ and $C_{no\ scrapping}$ are used to ensure that the model reproduces the exact probability of scrapping for the base year 2003 for each car age category. When the price of older second-hand cars changes as a result of an imbalance between supply and demand, the scrapping probability also changes in the dynamic scrapping model. The scrapping prob-

Table 3
Coefficients in the type choice module for company cars.

Variable	Coefficient	|t-Value|
Costs (€000)		
Ln(lease costs)	−0.084	0.6
Lease costs for the driver	−2.931	6.4
Costs for income tax	−0.076	0.8
Var. costs paid by driver	−0.085	0.6
Supply		
Ln(Size)	1.268	5.8
Car type		
Gasoline	−1.020	4.8
Diesel	1.436	6.2
LPG	−0.416	–[a]
Observations	RP: 137 × 1	SP: 407 × 12
Alternatives	RP: 12	SP: 6
Model fit (Pseudo R^2)		0.022

[a] Reference category.

ability of a vehicle will decrease if the car becomes more valuable and will increase when the car becomes less valuable, if a scrapping subsidy can be obtained and/or if repair costs increase.

The parameters in the model were estimated using stated preference data that were collected for this purpose. This dataset contains 1039 respondents who owned a car that was 10 years or older. The SP data include attributes regarding the residual value, road tax levels, repair and maintenance costs, and various subsidy levels for scrapping cars. The 952 respondents in the SP subset had to choose from 18 choice sets, each containing two options (either scrap your car or do not scrap your car). Table 4 shows the results.

Table 4 shows that coefficients have expected sign and that the model has a good overall fit. All of the coefficients are significant (except the coefficient associated with the variable that represents the probability of finding another car, which does not affect the probability of scrapping). The coefficients for the probability of finding a replacement car and for the chance of having unexpected repairs are not included in the car scrapping module of Dynamo.

Two approaches are used to validate the model. The effects of several price policies are simulated, and long- and short-term output elasticities are derived and then compared with known values. Second, the car fleet was backcasted from 2003 to 1998 and 1990 and compared with outcomes using available statistics. These elasticities proved to be within ranges reported (MuConsult, 2002) and indicate that the model reproduces the car fleet and the development of the price of second-hand cars for 1998 well. It performed less well for 1990.

4. Reference and distance-based user charging scenarios

The Dutch government uses four long-term scenarios to describe population, economic and spatial developments through 2040 and we use projections from one of these, Strong Europe, which involves modest population and employment growth (Janssen et al., 2006). Two variants of this with respect to the tax structure for cars are explored. The first assumes that the taxation structure will remain similar to 2003 over the forecast period (SE), and the other that vehicle costs will be influenced by future planned Dutch fix tax changes (SEtax). Under the Dutch tax plans, fixed car taxes will depend increasingly on emissions of CO_2 and other pollutants. This plan began in 2006 with a tax penalty or a reduction in the purchase tax, depending on a vehicle's CO_2 emissions; i.e., a tax break for a car with relatively low emissions, and higher taxes for a car with higher emissions. In 2010, the first step was taken towards making purchase tax dependent strictly on the absolute level of CO_2; a process to be completed in 2013. Furthermore, after 2006, several other penalties and bonuses were introduced for driving cars that are either less or more fuel efficient through road or purchase taxes, and the amount of income tax to be paid on a company car. For example, in 2010 no purchase tax and no road tax are charged for a car emitting less than 110 g CO_2/km for gasoline and LPG cars, and less than 95 g CO_2/km for diesel cars. For both situations, the same assumptions are made with respect to fuel prices, the number and distribution of household types, and other non car-tax-related characteristics.

Table 4
Coefficients of the car-scrapping model.

Variable	Coefficient	|t-Value|
Subsidy		
Cash (no conditions)	0.077	2.5
Subsidy when buying another car	0.041	1.2
P(finding other car)		
Small (<35%)	−0.185	6.0
Average (35–65%)	0.181	6.8
Large (>65%)	0.004	–[a]
Residual value minus subsidy		
(Linear)/1000	0.548	26.8
Repair costs		
(Linear)/1000	−1.066	9.6
Road tax		
20% Lower	0.573	16.4
Same as now	−0.028	1.0
20% Higher	−0.546	–[a]
P(unexpected repairs)		
Small (<35%)	0.015	0.5
Average (35–65%)	0.009	0.3
Large (>65%)	−0.024	–[a]
Constant = 1 when no scrap	1.193	30.1
Model fit (Pseudo R^2)		0.32

[a] Reference category.

To assess the potential effects of environmentally differentiated user charging, we examined the following charging scheme; a flat rate scheme, an environmentally differentiated scheme, and a scheme that maximizes the reduction of CO_2 emissions. In all cases, the variants are developed assuming budget neutrality; an explicit political constraint. The Dutch Ministry of Transportation developed three scenarios. The flat variant has a charge of €0.067 per kilometer. This price level is determined by the current revenue from vehicle purchase taxes together with a correction for the expected drop in both demand and operating costs needed to generate the necessary returns. The environmentally differentiated variant was developed based on the following criteria taking into account for political acceptability:

- Differentiation based on CO_2. The choice of CO_2 as the basis for the 2010 purchase tax is consistent with the broad desire for base rates per kilometer to reflect the environmental performance of vehicles.
- Changes in existing road taxes and purchase taxes. One consideration in redistributing the tax rates is to remain close to the current system and to minimize changes in the used and new car markets.
- A price premium for particulate emissions for diesel cars that do not have an after-market particle filter. The proportion of cars sold without a particulate filter will gradually decrease over time and a price premium will accelerate this.

Fig. 2 summarizes the distance-based charges in 2012 by fuel type and CO_2 class, assuming that the distance-based charges are fully implemented. In the policy's proposals for distance-based user charges, implementation was anticipated to be gradual between 2012 and 2018. After 2012, there would be an annual adjustment in charges to correct for the decline in diesel cars sold without a particulate filter, and the increase in autonomous technical development emissions from the entire fleet.

Finally, a variant was developed to maximize the reduction in CO_2 emissions without raising tax revenue. This variant takes into account the distribution of the car fleet. The curve of the charge is sigmoidal (S-shaped) in this variant. The steepest part of the curve is where most cars are present and where the CO_2 emissions/km is on its average value. Here, the charge is about the average value (€0.067). In this variant, owners of cars with emissions that are above (or just above) the average level can reduce their car costs substantially simply by changing to a more fuel-efficient car. Because this holds for many cars, the CO_2 reduction will be relatively high in this variant. As cars become more full-efficient over time (due to technological improvements and/or changes in behavior), the S-curve will shift to the left to ensure that maximum "pressure" is placed on owners of a car with higher-than-average emissions to obtain a more fuel-efficient car while keeping the overall average distance-based charge constant.

5. Results

Dynamo provides detailed output for each year and a selection of outcomes for 2003 (the base year), 2010, 2020 and 2030 is given in Table 5. It shows that the tax reform, particularly the introduction of CO_2-dependent road and purchase taxes,

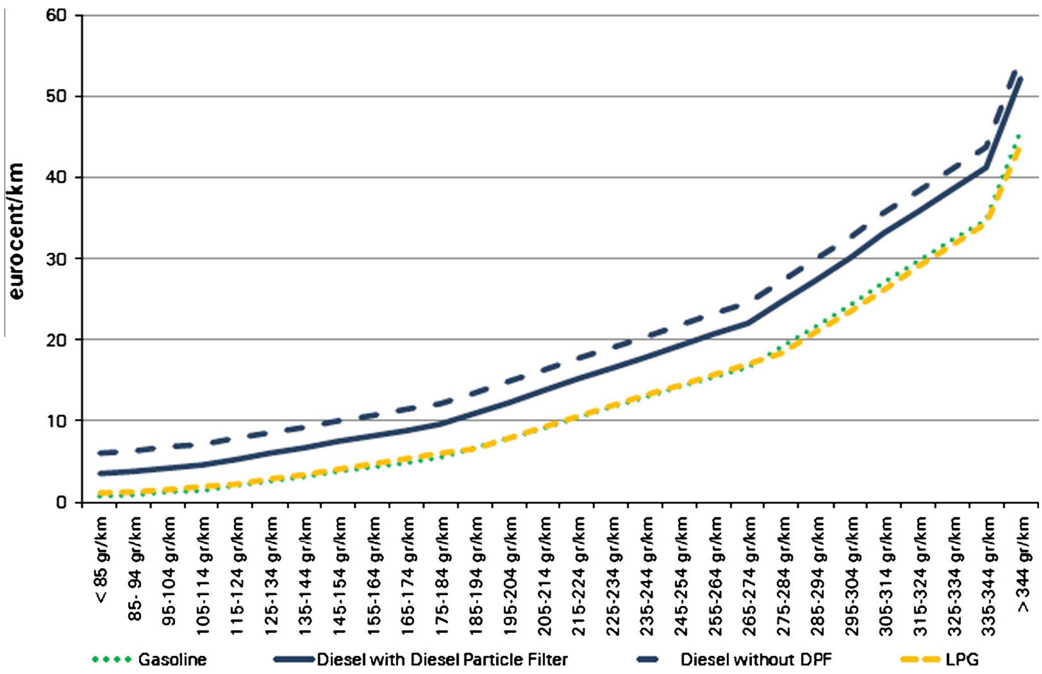

Fig. 2. Distance-based user charges in 2012 (2009 prices).

results in a relative shift towards smaller, fuel-efficient cars reducing CO_2 emissions from an average car by 6 g/km by 2030, but increases car ownership by 2% in 2030. Purchase and road taxes are reduced to zero for small, highly fuel-efficient cars, which reduces the average car price and increases car ownership. The new tax system also reduces vehicle weight relative to the old system, but cars will still become heavier from 2003 through 2030 as a result of safety and quality improvements.

The new tax system only has a small effect on the distribution of fuel type and average mileage because it is aimed primarily at fixed costs and is constructed so that current differences in costs between fuel types basically remain. The number of kilometers driven increases slightly in the SEtax compared to the SE scenario, because cars become cheaper to use as average fuel consumption falls, as reflected in reductions in CO_2 emissions per kilometer.

The new tax system will reduce CO_2 emissions from the Dutch car fleet by about 4% in 2030, despite an increase in the number of cars, due primarily to the higher average tax placed on large (less fuel-efficient) cars and a lower tax placed on small (more fuel-efficient) cars. This change in tax will lead to a general shift towards smaller, more fuel-efficient cars. In 2030, the proportion of the heaviest weight category will be 35.2% and 29.3% in the SE and SEtax scenarios.

Table 6 shows the Dynamo model estimates for the three distance-based charging schemes as described earlier: the flat rate, the environmentally differentiated scheme and the CO_2-optimized car user charge.

The three distance-based user charging schemes result in a decrease in car use, but they also result in an increase in car ownership by 3–6% in 2030 compared to the reference scenarios. Compared to the reference scenario with the tax reform plan, the charging schemes result in an unintended increase in both diesel cars and relatively large, heavy vehicle types, and this increase results in an increase in the average emissions per kilometer in two of the schemes compared to the reference scenario with the tax reform. These unintended effects can be explained by the fact that households react more strongly to one-time fixed costs than to recurring variable costs with respect to their car purchase behavior. In addition, car costs are reduced for households with relatively low car usage. Compared to the SE scenario without the tax plan, the average emissions per kilometer are lower in all cases, however. CO_2 emissions from cars decrease by 8–13%, compared to the reference scenario with or without the tax reform. The reduction in kilometers driven per vehicle is clearly far more important than the forecasted changes in the size and composition of the fleet.

When the Dynamo projections for the environmentally differentiated distance-based pricing variant are compared with the flat price variant, it becomes clear that the latter leads to smaller reductions in the car age and the percentage of diesel cars. Furthermore, a flat charge results in a heavier, and therefore less fuel-efficient, fleet; i.e., CO_2 emissions per kilometer driven will increase by some 6% by 2030. The average amount of CO_2 emissions per kilometer is even higher than the emissions in the SEtax system. As expected, the differences in the impact on national car ownership and car use levels are extremely small.

When we compare the environmentally differentiated variant with the CO_2-optimized alternative, we see that the former results in about the same fleet size, mileage, car age and car price. The CO_2-optimized variant results, however, in lower average CO_2 emissions, lighter vehicles, and a higher percentage of diesel-powered vehicles. Thus, we see that as the price curve becomes "steeper" in the range in which most cars are included, the pressure on car owners to own a more fuel-efficient car increases. This relationship suggests that more car owners will be confronted with higher costs when they continue to own a car that is slightly less fuel-efficient than an average vehicle.

Table 5
Dynamic estimates for the reference scenarios.

Variable	SE reference				SEtax reference		
	2003	2010	2020	2030	2010	2020	2030
Fleet size (millions)	6.9	7.7	8.8	9.9	7.8	9.0	10.1
Mileage (km)							
Average per car/year	16,231	16,390	16,406	16,194 1	6323	16,252	16,019
Fleet (billion)[2]	98	111	127	141	111	128	142
CO_2 emissions (g/km)							
All cars[a]	193	185	165	150	183	160	144
New cars[a]	189	171	159	140	167	152	133
New cars test value	174	154	145	127	150	138	121
CO_2 (mega tonnes)[b]	19.3	20.7	21.3	21.5	20.6	20.8	20.7
Fuel mix (%)							
Gasoline	81.2	78.3	79.7	80.4	78.5	80.1	80.9
Diesel	14.8	19.1	18.7	18.3	19.0	18.4	18.1
LPG	4.0	2.6	1.6	1.3	2.5	1.4	1.0
Car weight (%)							
<951 kg	36.8	22.6	16.3	15.6	23.0	19.7	19.8
951–1150 kg	30.2	26.7	23.8	23.4	26.7	24.4	24.3
1151–1350 kg	22.8	27.9	27.1	25.8	27.9	27.3	26.5
>1350 kg	10.2	22.9	32.8	35.2	22.5	28.6	29.3

[a] Average per car per kilometer driven.
[b] Excluding kilometers driven abroad.

Table 6
Dynamo model estimates for distance-based car user charging schemes.

Variable	Flat rate		Environmentally differentiated		CO^2 optimized	
	2020	2030	2020	2030	2020	2030
Fleet size (millions)	9.1	10.4	9.1	10.5	9.2	10.5
Mileage (km)						
Average km/year	14,355	13,960	14,358	13,948	14,357	13,930
Fleet total (billion)	114	127	115	127	115 1	28
CO_2 emissions						
All cars (g/km)	167	156	161	147	157	143
New cars (g/km)	168	147	157	138	152	134
Test value (g/km)	152	133	143	126	139	123
CO_2 (mega tonnes)	19.3	20.1	18.7	19.0	18.4	18.6
Fuel mix (%)						
Gasoline	79.0	78.7	77.8	76.8	74.9	71.6
Diesel	19.6	20.3	20.7	22.0	23.7	27.4
LPG	1.4	1.0	1.5	1.3	1.4	1.0
Car weight (%)						
<951 kg	15.0	10.4	15.8	12.3	15.9	12.5
951–1150 kg	22.1	18.7	22.5	0.0	22.8	20.8
1151–1350 kg	27.4	26.2	26.9	25.6	26.7	25.3
>1350 kg	35.5	44.7	34.8	42.1	34.6	41.3
Car age (year)	8.2	8.0	8.2	7.9	8.2	8.0
Car prize (index 2003 = 100)	81	70	80	69	80	69

6. Conclusions

The potential impacts of distance-based car user charges on the Dutch car market are examined using the Dynamo car market model. We find that replacing existing car purchase and road taxes with a CO_2-differentiated distance-based user charge has unintended consequences on the size, composition and environmental performance of the car fleet. The tax-charging schemes result in increasing levels of car ownership, a higher percentage of diesel-powered cars and more vehicle types that are relatively large and heavy. These unintended effects are the result of households reacting more strongly to one-time fixed costs than to recurring variable costs, and car costs are reduced for households with relatively low car usage. Without including a CO_2 differentiation factor in the distance-based user charge, the increase in vehicle weight and decrease in fuel efficiency would be larger. Nevertheless, the net environmental impact of distance-based charges is still positive due to the reduction in car travel.

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