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WORKING PAPER NO. 134

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This paper was presented at the CEPR/ECB Workshop on "Issues in the Measurement of Price Indices", held at the European Central Bank on 16/17 November 2001.

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ISSN 1561-0810

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Abstract

User-cost indexes provide important information about the welfare implications of durable goods purchases. In this paper indexes for the cost of private transportation are developed, based on the costs associated with using new passenger cars sold in 1992-1999, in the Netherlands.
The paper examines the existence of differences between car model based user-cost indexes and CPI based indexes. Use is made of information about prices and technical characteristics of about 7,000 car models. In addition, data on user costs are used.
The results show that total annual user costs have increased about 4.8% over the observation period vs. 10.6% according to the CPI based index. Fixed costs have increased about 9% both for the car model and the CPI based index. Operating costs have *de*creased more than 3% according to the car model based index, whereas an *in*crease of more than 13% is observed for the CPI based index.

Key words: Consumer Price Index, User-Cost Index

JEL-classification codes: C43, D12, E31

Non-technical summary

In this paper the user-cost approach is applied to the estimation of cost developments for private transportation in the Netherlands. The estimates are based on a large amount of ANWB/RDC information about prices, technical characteristics and sales of new cars sold in the Dutch passenger car market in the period 1992-1999. In addition, ANWB information on user costs is employed.
The publication of the findings of the CPI Commission (Boskin *et al.*, 1996) has led to world wide renewed interest for the problems of price and volume measurement. The report concludes that the Consumer Price Index (CPI) in the U.S. has an upward bias of 1.1 percentage points per year. A large part of this bias (0.6 percentage points) is attributable to the difficulties associated with adjusting for quality change and the introduction of new goods.
Several suggestions have been made for improving the treatment of on-going quality developments of products and services. One example is the use of *hedonic* models for price measurement. In this view (durable) goods are treated as bundles of technical characteristics. The price of the bundle is assumed to equal the sum of the (implicit) prices of the characteristics that constitute the bundle. As a result of quality change prices of new and old products cannot directly be compared. By focusing on product *characteristics* rather than products, we can get around the problem of adjusting for quality change: although new products do not have antecedents in existing products, they usually do have antecedents in existing characteristics.
Though focusing on product characteristics rather than products, the hedonic method still aims at measuring prices of the *commodities bought*. An alternative approach was advocated by Nordhaus (1997, 1998) among others. He argues that 'at the most fundamental level, the problem of quality change arises because conventional price indexes measure the prices of commodities that consumers buy rather than the cost of attaining a given level of economic well-being or *utility*. It is of course impossible to measure utility directly, so the next approach would be to measure the prices of the fundamental characteristic *services* that consumers value. These would include transportation, communication, good health, entertainment, and so forth' (1998: 59-60). According to Nordhaus the CPI in reality moves 'yet another logical step away' by measuring the prices of *inputs* (like automobiles, electricity and hospital days) that consumers buy to 'produce' the fundamental services (like travel, lighting and delivering a baby). Therefore, in trying to improve the measurement of the cost of living one should focus on prices of the fundamental services rather than prices of inputs.
The recent paper of Schultz (2001) is an example of such an attempt. He examines the possibility to estimate price changes for private transportation in Canada by focusing on user-costs. User-cost index series were calculated separately for Toronto and Montréal, each with specific scenarios of travel patterns, road surface, terrain and climate conditions. For these cities also CPI data are available. Schultz found minor differences between the CPI approach and the user-cost approach with respect to total *fixed* costs. The results for *operating* costs, on the other hand, showed larger divergences, especially for Montréal.
The present paper studies the situation for the Netherlands. The purpose is to investigate whether the user-cost principle leads to different estimates of cost developments for private transportation in the Netherlands as compared with the current CPI method. Use is made of information about prices and

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technical characteristics of about 7,000 car models sold in the Dutch passenger car market in the period 1992-1999.

Both annual user costs and user-costs-per-kilometer have been estimated for each car model and each year of observation. The user costs consist of fixed costs (depreciation, insurance premium and road tax) and operating costs (maintenance and fuel consumption). Car model based user-cost indexes that reflect the development of actual (annual and unit) user costs have been calculated and a comparison has been made with a CPI based user-cost index.

Both the car model and the CPI based index for total user costs on the average show an increase over the 1992-1999 period. The car model based annual user-cost index increases 4.8% (unit user-cost index 4.0%) over the entire period implying an average annual growth of 0.67% (unit user-cost index 0.56%). The index value in the final year, however, may be slightly biased downward due to the use of January 1 fuel prices. The CPI based index increases 10.6% ($AAG = 1.45\%$).

Differences between car model and CPI based indexes are largely attributable to different developments of fixed and operating costs. Fixed costs have increased about 9%, both for the car model and the CPI based indexes. Large differences on the other hand are observed for operating costs. The CPI based operating costs index *in*creases more than 13% whereas the car model based index *de*creases about 3% during the observation period. The reduction of operating costs, and maintenance costs in particular (-11%; $AAG = -1.65\%$), according to the car model based index, is a result of the 'continuous improvements of the durability of passenger cars', as expected in Bode and Van Dalen (2001: 16).

The results of this study generally conform those of Schultz (2001), who also found minor differences with respect to total *fixed* costs, but larger divergences for *operating* costs (especially for Montréal). However, contrary to Schultz' findings for operating costs our user-cost estimates show a *de*crease (instead of an *in*crease even *stronger* than average annual growth of the CPI based index for operating costs).

Some issues require further attention in future research. For instance, following the ANWB information each car model has been given a *fixed* yearly kilometrage and given this kilometrage a *uniform* distribution of lifespans over the range of possible lifespans is assumed. It is unclear how this assumption affects the estimates of user costs (developments). More information about driving behavior of private car owners is necessary in order to answer this question. Another issue is the nature of ANWB user-cost information. The estimates are based on price and cost information that is available at the *beginning* of a year. There is no reason to assume that this may lead to *systematic* biases, but further research is necessary. Some of the CPI commodity groups used in this study relate to both *new* and *used* (second hand) cars, as well as *other* vehicles, such as motors cycles. Use has been made of a relatively high level of aggregation of CPI groups, especially in case of the 'old' situation before 1995. Also here further research at a more disaggregate level would be necessary to study the consequences for the CPI based user-cost index results.

Although these issues ask for some caution in drawing definite conclusions, the results of this study provide empirical support for the idea that application of the user-cost principle leads to different estimates of cost developments for private transportation than the current CPI method

1. Introduction

The publication of the findings of the CPI Commission (Boskin *et al.*, 1996) has led to world wide renewed interest for the problems of price and volume measurement. The report concludes that the Consumer Price Index (CPI) in the U.S. has an upward bias of 1.1 percentage points per year. A large part of this bias (0.6 percentage points) is attributable to the difficulties associated with adjusting for quality change and the introduction of new goods; also see Boskin *et al.* (1997, 1998).
Several suggestions have been made for improving the treatment of on-going quality developments of products and services. One example is the use of *hedonic* models for price measurement.[2] In this view (durable) goods are treated as bundles of technical characteristics. The price of the bundle is assumed to equal the sum of the (implicit) prices of the characteristics that constitute the bundle. As a result of quality change prices of new and old products cannot directly be compared. By focusing on product *characteristics* rather than products, we can get around the problem of adjusting for quality change: although new products do not have antecedents in existing products, they usually do have antecedents in existing characteristics. This approach was recently applied to estimate quality-corrected price indexes of new passenger cars in the Netherlands (see Bode and Van Dalen, 2001).[3]
Though focusing on product characteristics rather than products, the hedonic method still aims at measuring prices of the *commodities bought*. An alternative approach was advocated by Nordhaus (1997, 1998) among others. He argues that ‘at the most fundamental level, the problem of quality change arises because conventional price indexes measure the prices of commodities that consumers buy rather than the cost of attaining a given level of economic well-being or *utility*. It is of course impossible to measure utility directly, so the next approach would be to measure the prices of the fundamental characteristic *services* that consumers value. These would include transportation, communication, good health, entertainment, and so forth’ (1998: 59-60). According to Nordhaus the CPI in reality moves ‘yet another logical step away’ by measuring the prices of *inputs* (like automobiles, electricity and hospital days) that consumers buy to ‘produce’ the fundamental services (like travel, lighting and delivering a baby). Therefore, in trying to improve the measurement of the cost of living one should focus on prices of the fundamental services rather than prices of inputs.[4]
The issue is illustrated in Nordhaus (1997) by developing a price index of ‘light’, treating light as input in the utility function, and the consumption of electricity and bulbs as inputs in a production function of light. Next the ‘true’ price index of light (defined as the ratio of the costs of a lumen-hour in the current year and in the base year) is compared with the conventional consumer price index for light (based on price indexes for electricity and bulbs). It appears that over the 1800-1992 period the conventional price of light has risen by a factor of about 1000 relative to the true price, which amounts to an average annual bias of 3.6 percentage points.
Others have applied this approach in the area of medical care where treatments are subject to technological improvement. Shapiro and Wilcox (1996) present a price index for cataract surgery that is based on the treatment itself, i.e. the restoration of eyesight impaired by cataracts. They show that this index grows much more slowly than a price index for cataract surgery that is constructed using the CPI methodology, i.e. based on inputs such as an hour of a physician’s time, a day in the hospital

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[2] This approach has been introduced in economics by Court (1939) with an analysis of automobile prices, and enhanced by Griliches (1961, 1971), and Adelman and Griliches (1961). See Triplett (1986) for a further discussion of this method as well as other references.
[3] In this hedonic analysis we employed the *time-age-vintage* models originally developed by Hall (1971) for the second-hand pick-up truck market, adopted by Oliner (1993) to explain price developments in the mainframe computer market, and more recently applied by Berndt, Griliches and Rappaport (1995) to explain price decreases of PC’s.
[4] Pricing of inputs rather than outputs is not fundamentally inconsistent with adequate adjustment for quality change as long as the input prices are adjusted for changes in their efficiency in delivering consumer satisfaction, as noted by Shapiro and Wilcox (1996); however, relatively few such adjustments are made.

and a basket of prescription drugs. According to the prototypical[5] index, the price of cataract treatment increased over the sample period 1969-1993 by a factor of about 3, whereas the hypothetical index increased over the same period by a factor of nearly 10.

Another example is given by Van Tuinen, De Boo and Van Rijn (1998), who apply this principle to construct a price index for appendectomy treatments. They argue that if *complementarity* exists between different commodities (inpatient days, physicians operations) it is the *combination* of the complementary commodities (the appendectomy treatment) which is relevant to the consumer. Also in their paper, at the end of the sample period the prototypical price index is substantially lower than the hypothetical index. The prototypical index increases by an average rate of 1.5% per year as against 4.4% increase per year for the hypothetical index.

The potential effects on price and volume statistics of taking the complementarity of commodities into account are important, as Van Tuinen *et al.* conclude (p.250). This is not only true for medical services, but also in areas like mobility. With respect to this area they note: ‘Why shouldn’t we try to estimate a price index of vehicle kilometers instead of separate price indices of vehicles, repairs, fuel, insurance, etc.?’ (p.245).

The recent paper of Schultz (2001) is an example of such an attempt. He examines the possibility to estimate price changes for private transportation in Canada by focusing on user-costs. In his paper Schultz makes use of empirical data about the cost of owning, maintaining and using automotive vehicles provided by a private company that specializes in the estimation of various business costs. The data cover the period from 1988 to 2000, and relate to 12 models of private cars produced by three major North-American manufacturers. User-cost index series were calculated separately for Toronto and Montréal, each with specific scenarios of travel patterns, road surface, terrain and climate conditions. For these cities also CPI data are available. Schultz found minor differences between the CPI approach and the user-cost approach with respect to total *fixed* costs. The results for *operating* costs, on the other hand, showed larger divergences, especially for Montréal. At the general *total* level in the year 2000 the differences between the CPI and user-cost series amount to less than 1% for Toronto, but to more than 10% for Montréal. Schultz concludes: ‘Such an irregular relationship suggests that the differences are more likely due to data collection problems than to conceptual or methodological problems. Further thorough investigation will be necessary to explain some other discrepancies’ (p.13).

The present paper studies the situation for the Netherlands. The purpose is to investigate whether the user-cost principle leads to different estimates of cost developments for private transportation in the Netherlands as compared with the current CPI method. Basically we follow the same procedure as Schultz, but there are some differences. First, our analysis is based on a ‘full coverage’ of the car market. Use is made of information about prices and technical characteristics of about 7,000 car models sold in the Dutch passenger car market in the period 1992-1999. Secondly, index series are constructed on an aggregate (country) level, whereas Schultz develops price indexes for two cities. Thirdly, Schultz calculates costs assuming new cars are sold after 4 years and car owners drive 15,000 kilometers per year, whereas in our analysis both lifespan and yearly kilometrage varies by car model.

The study is structured as follows. The next section discusses the data used and the construction of user-cost indexes. In Section 3 the outcomes of various user-cost indexes are presented and compared to each other. Section 4 concludes the paper.

[5] Shapiro and Wilcox (1996) call the treatment based index a *prototypical* index. The CPI based index is called a *hypothetical* index.

2. Data sources and construction of user-cost indexes

In this section a description is given of the data used. The available information on user costs is discussed first. Specific attention is paid to the way in which various data sources are merged; also see Bode and Van Dalen (2001). Based on the available information user-cost indexes are defined. Next we describe the CPI data that are used for comparison purposes and the construction of CPI based user-cost indexes.

User-cost data

Information about prices, technical characteristics, and sales of passenger cars in the Netherlands come from two different sources: ANWB and RDC.[6] The ANWB file contains detailed information about the price and technical characteristics of about 10,000 passenger car models offered for sale in the Dutch new car market in the period 1992-1999. The RDC file contains information about the actual sales and a limited set of technical characteristics of about 32,000 new car models sold to private consumers in the same 1992-1999 period. Since both data sources cover the entire car market, it is clear that the definition and registration of car models must differ widely.

This issue is dealt with extensively in Bode and Van Dalen (2001) where the same data[7] are used to estimate quality-corrected price indexes for new passenger cars using hedonic methods. As explained there, the resulting merging problem has been solved by the definition of three identification keys that fit both ANWB and RDC information: a *brand* key, a *model* key and a *type* key. The actual merging of the data sources has been performed by each of the three keys and year. For example, in case of the most detailed identification key (*type*), the sales volume in year t of a car model (record) in the ANWB file is determined (estimated) by dividing the total number of new cars of the corresponding *type* sold in year t to private consumers (RDC information) by the number of ANWB car models (records) having this *type* value. The average sales per car model, evaluated at the levels of *brand*, *model* and *type*, have been used as weighting variables in the hedonic analyses.

In the present paper this ANWB/RDC file of (average) yearly prices and sales figures of new passenger cars also serves as the starting point of analysis. The ANWB/RDC data are merged with user-cost information extracted from a third data base that could also be obtained from ANWB for the years 1992-1999. We call this ANWB data file the 'UCE' (user-cost estimates) file in order to distinguish it from the former ANWB(/RDC) file. The procedure followed by ANWB to produce these estimates is explained briefly.

Each year ANWB constructs tables providing a good indication of *expected*[8] user costs per kilometer for new passenger cars. At the beginning of a year all new passenger car models that are available in the Dutch market place are partitioned into price classes based on the consumer price on January 1.[9] Petrol cars and diesel cars are treated separately. For both fuel types and for each price class the average car price is determined. Next for this 'average car', user-costs-per-kilometer are estimated

[6] ANWB refers to the Royal Dutch Tourist Office, which attends to the interests of tourists an road users in the Netherlands. RDC refers to the RAI Data center, which is responsible for car registrations in the Netherlands.

[7] The data used in Bode and Van Dalen (2001) refer to the years 1990-1999. (Only the first 5 months of 1999 are observed.) In the present study the data before 1992 are not part of the analysis because user-cost information is only available for the 1992-1999 period.

[8] Note that ANWB does not provide information on *actual* (realized) user costs, but on costs to be *expected* based on available information at the beginning of a year.

[9] The definition of price classes differs from year to year. This holds both with respect to the minimum or maximum car prices used, and with respect to the specification of the class intervals themselves. Very cheap as well as very expensive cars do not occur in the UCE file because the relatively small number of sales for these cars frustrate a reliable estimate of user costs. In this study for convenience sake we take *equal* price limits in all sample years (1992-1999). That is, petrol car prices range from DFL 15,000 to DFL 100,000 and diesel car prices from DFL 26,000 to DFL 90,000 in all years. In our hedonic study neither cheap nor expensive cars are discarded.

per category of costs,[10] depending on the yearly kilometrage and the lifespan (the number of years of use) of the car.[11]

In order to merge the UCE data with the ANWB/RDC data, the car models in the ANWB/RDC file are similarly partitioned into price classes on the basis of their (average) yearly prices. Each car model in the ANWB data file has its own 'standard yearly kilometrage',[12] which is supposed to be the *expected* yearly kilometrage of this car model. Given this assumption and given fuel type, year of observation and price class of a car model in the ANWB/RDC file, it is now possible to find the corresponding *average* user-costs-per-kilometer figures for this car model from the UCE data, where costs are averaged over all available lifespans.[13] We implicitly assume that the *actual* lifespan of a car model is uniformly distributed over the corresponding range of possible lifespans given in the UCE data. For example, according to the UCE file the lifespan of a diesel car with a kilometrage of 40,000 km per year varies from 1 to 5 years. Hence the average user-costs-per-kilometer figures for such a car are calculated as the arithmetic means of the five separate user-cost figures corresponding with the five lifespans (for the respective year of observation and the respective price class).

Based on these ANWB/RDC/UCE data partial and aggregate uses-cost indexes can be constructed. In this study the eight cost elements defined by ANWB (see Footnote 10) are regrouped to enable comparability between the UCE data and CPI data to be described below. Table 1 shows the various user-cost components to be used for index construction.

Table 1 – User-cost elements

Name	*Description*
Fixed costs:	
DEPRE	Total depreciation (economic + technical)
INSUR	Insurance premium (Third Party Liability + hull insurance; No-Claim discount varying from 40 to 50%, based on nationwide average)
ROTAX	Road tax
Operating costs:	
MAINT	Maintenance and repairs (coach-work/technical maintenance + tires)
FUELC	Fuel consumption

Indexes can be determined on a per-kilometer base (unit user costs) and on an annual base (annual user costs). Both approaches are explained.

A straightforward way to measure developments of unit user costs of new passenger cars in the Netherlands over the observation period 1992-1999 is by directly comparing the average user-costs-per-kilometer in a specific year with the average costs in the base year 1992. Let A_t be the index set of new passenger car models in year t; c_{it} the user-costs-per-kilometer of car model $i \in A_t$ (averaged over available lifespans); q_{it} the sales volume of car model i. Then the average user-costs-per-kilometer $\bar{c}_t$

[10] ANWB considers 4 categories of *fixed* costs (economic depreciation, insurance, road tax and coach-work maintenance) and 4 categories of *operating* costs (technical depreciation, fuel consumption, technical maintenance and tires).

[11] ANWB calculates user costs for kilometrages varying from 10,000 to 80,000 km per year and lifespans varying from 1 to 7 years. Not all combinations of kilometrage and lifespan are considered. In practice higher yearly kilometrages usually occur in combination with smaller lifespans, and diesel cars usually have higher yearly kilometrages than petrol cars. The original UCE file contains 43 kilometrage-lifespan combinations for petrol cars and 35 combinations for diesel cars (within *each* price class). See also Footnote 13 below.

[12] These kilometrages are: 15,000 km for small petrol cars; 20,000 km for large petrol cars; 30,000 km for small diesel cars; and 40,000 km for large diesel cars.

[13] As mentioned in Footnote 11, the lifespans are related to fuel type and yearly kilometrage. ANWB has made the following decisions: the lifespan of petrol cars driving 15,000 km per year varies from 2 to 7 years; for petrol cars driving 20,000 km per year this number varies from 1 to 7 years; for diesel cars driving 30,000 km per year this number ranges from 1 to 6 years; and for diesel cars driving 40,000 km per year the lifespan varies from 1 to 5 years.

in year t can be obtained as $\bar{c}_t = \sum_{A_t} w_{it} c_{it}$. Here w_{it} stands for the fraction of car model sales q_{it} in total new car sales in year t, $w_{it} = q_{it} \big/ \sum_{A_t} q_{it}$, $\sum_{A_t} w_{it} = 1$. The unit user-cost index $IUUC_t$ now follows for every year t (= 93, …, 99; $IUUC_{92}$ =1) as:[14]

$$IUUC_t = \frac{\bar{c}_t}{\bar{c}_{92}} = \frac{\sum_{i \in A_t} w_{it} c_{it}}{\sum_{j \in A_{92}} w_{j92} c_{j92}} \tag{1}$$

As explained above, the (average) sales volume q_{it} per car model can be evaluated at the level of *brand*, *model* or *type*. In this paper we only use *type* level based sales estimates. Applying (1), unit user-cost indexes can be calculated separately for each cost component in Table 1, but also for aggregates of user cost components.

Annual user-cost indexes are determined in a similar manner. Let km_i be the standard yearly kilometrage (see Footnote 12) of car model $i \in A_t$. Then the annual user costs C_{it} (averaged over available lifespans) of car model i can be determined as $C_{it} = km_i \times c_{it}$ and the annual user-cost index $IAUC_t$ follows for every year t (= 93, …, 99; $IAUC_{92}$ =1) as:

$$IAUC_t = \frac{\bar{C}_t}{\bar{C}_{92}} = \frac{\sum_{i \in A_t} w_{it} C_{it}}{\sum_{j \in A_{92}} w_{j92} C_{j92}} \tag{2}$$

The unit-cost index (1) is based on the idea that the ‘fundamental service’ provided by a (new) car is a ‘car-kilometer’, just like Nordhaus (1997) focuses on a ‘lumen-hour’ and Shapiro and Wilcox (1996) on a ‘cataract surgery’. The annual user-cost index (2), on the other hand, could be grounded on the view that the service provided by a car is a ‘car-year’. In addition, index formula (2) is more appropriate when a comparison with current CPI practices has to be made. Schultz (2001) also annualizes user costs.

CPI data

Judging (1) and (2) requires an official ‘private transportation’ index for new passenger cars. This is not directly available from CPI, but can be constructed using price developments of several CPI commodity groups. Table 2 presents an overview of these CPI groups.

In 1995 all CPI commodity groups were redefined and re-weighted by Statistics Netherlands (SN). The 1990 and 1995 weights mentioned in the table can be transformed into budget shares dividing them by 100,000. For example, in 1995 new car purchases constitute 3.325% of total consumer expenditures. In pairing the old and new commodity groups for the current study use is made of Bovelander (1998).[15]

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[14] Alternative *matched model* indexes might be defined considering only car models that appear in two consecutive years; also see Bode and Van Dalen (2001). We abstained from using these indexes in the present paper. It may be subject for further research.

[15] As a result of the change of definition sometimes there is not a perfect match. For example, the new commodity group ‘Parts and accessories of private vehicles’ (07.2.1) does not correspond completely with the old group ‘Parts and accessories’ (6400); the new group 07.2.1 also contains some commodities belonging to the old group ‘Repair and maintenance’ (6470).

Table 2 – CPI commodity groups used for user-cost index construction

UCE file Variable Name	CPI (all households; 1990=100) Commodity group Description	SN Code	1990 Weight	CPI (all households; 1995=100) Commodity group Description	SN Code	1995 Weight
Fixed costs						
DEPRE	Purchase cars new	6000	2580	Purchase new cars	07.1.1.1	3325
INSUR	Insurance vehicle	6650	1410	Car insurance	12.4.4A.1	1318
ROTAX	Road tax	9040	1020	Road tax	13.1.1.5	1350
Operating costs						
MAINT	Parts and accessories	6400	450	Parts and acc. private vehicles	07.2.1	435
	Repair and maintenance	6470	1050	Maintenance and repair	07.2.3	868
				Technical inspections	07.2.4A.4	37
	Lubricant	6605	120	Oil and lubricants	07.2.2.4	23
FUELC	Petrol	6575	2260	Petrol	07.2.2.1	2736
	Diesel	6590	210	Diesel	07.2.2.2	176
Total			9100			10268

Using these data, CPI based user-cost indexes are constructed as follows. Developments of *individual* user-cost elements can directly be determined by linking the price indexes of corresponding individual commodity groups. That is, for each pair k of CPI commodity groups mentioned in the rows of Table 2 the price index $ICPI_{kt}$ for year t (= 93, …, 99; $ICPI_{k92}$ = 1) is computed as

$$\begin{aligned} ICPI_{kt} &= \frac{ICPI^{(90)}_{kt}}{ICPI^{(90)}_{k92}} && (t = 93,...,95) \\ &= ICPI_{k95} \times ICPI^{(95)}_{kt} && (t = 96,...,99) \end{aligned} \tag{3}$$

Here $ICPI^{(b)}_{kt}$ stands for the price index of CPI commodity group k in year t with b (= 90, 95) as base year. The commodity groups 'Maintenance and repair' (07.2.3) and 'Technical inspections' (07.2.4A.4) are merged before the linking with commodity group 'Repair and maintenance' (6470) takes place. This results in the following index value $ICPI^{(95)}_{lt}$ (t = 96, …, 99) for this merged commodity group (say l):

$$ICPI^{(95)}_{lt} = \frac{w^{(95)}_{07.2.3} \times ICPI^{(95)}_{07.2.3t} + w^{(95)}_{07.2.4A.4} \times ICPI^{(95)}_{07.2.4A.4t}}{w^{(95)}_{07.2.3} + w^{(95)}_{07.2.4A.4}} \tag{4}$$

In order to construct user-cost indexes at a *higher* level of aggregation, the *individual* commodity group indexes (3) are combined using the CPI weights $w^{(90)}_{k}$ and $w^{(95)}_{k}$ of commodity group k as weighing variables. Let A be the index set of commodity groups that are to be combined. Then the aggregated index $ICPI_{At}$ follows for every year t (= 93, …, 99; $ICPI_{A92}$ =1) as:[16]

$$\begin{aligned} ICPI_{At} &= \sum\nolimits_{k \in A} v^{(90)}_{k} ICPI_{kt} && (t = 93,...,94) \\ &= \sum\nolimits_{k \in A} v^{(95)}_{k} ICPI_{kt} && (t = 95,...,99) \end{aligned} \tag{5}$$

Here $v^{(b)}_{k}$ stands for the share of the CPI weight $w^{(b)}_{k}$ in year b (= 90, 95) of commodity group k in the total weight of the index set A, $v^{(b)}_{k} = w^{(b)}_{k} \Big/ \sum\nolimits_{A} w^{(b)}_{k}$, $\sum\nolimits_{A} v^{(b)}_{k} = 1$.

[16] We have also calculated index values using either 1990-weights or 1995-weights throughout the observation period 1992-1999. The results, however, do not substantially differ from (5).

As formula (5) shows, the CPI based user-cost index is constructed as a weighted average of individual CPI commodity group (Laspeyres) indexes. The available CPI data do not allow for a *direct* comparison of (average) user costs in different years as in (1) or (2).

3. User-cost indexes for new passenger cars

Table 3 summarizes estimates of average annual user-cost levels and annual user-cost developments using index formula (2). It appears that average annual total costs (*TOTAL*) have increased about 5% during the observation period. The corresponding index value monotonically increases from 1992 unto 1998 (index value 1.104) and then sharply drops in 1999[17] to 1.048, implying an average annual growth (*AAG*) of 0.67% over the 1992-1999 period. Looking at the various cost components it appears that this overall increase is mainly due to the fixed cost elements. Average annual fixed costs (*FIXED*) have increased about 9% over the entire observation period (*AAG* = 1.22%), whereas average annual operating costs (*OPERAT*) have decreased 3.2% (*AAG* = –0.46%) in this period.
Looking more closely we see that particularly costs of maintenance and repairs have become much lower. In 1999 this cost level is 11% below the corresponding 1992 level (*MAINT*; *AAG* = –1.65%). This is in line with the fact that the quality of new passenger cars has improved over the last decade implying larger inter-overhaul times and lower maintenance costs. Fuel consumption costs have

Table 3 - Developments of annual user costs of new passenger cars, 1992-1999

		Fixed costs				*Operating costs*			*Total costs*
Year	*N*	*DEPRE*	*INSUR*	*ROTAX*	*TOTAL*	*MAINT*	*FUELC*	*TOTAL*	*TOTAL*
Level (DFL per year)									
1992	2157	5476	2087	639	8202	1630	2560	4190	12392
1993	2446	5706	2112	776	8595	1666	2533	4200	12795
1994	2766	5701	2609	840	9150	1680	2649	4329	13479
1995	2968	5727	2638	872	9237	1662	2630	4292	13529
1996	3342	5778	2704	860	9343	1585	2685	4270	13613
1997	3545	5836	2473	901	9210	1615	2851	4466	13676
1998	3369	5849	2484	833	9167	1516	2995	4511	13678
1999	2656	5654	2454	822	8930	1451	2606	4057	12987
Index (IAUC; 1992= 100)									
1992	2157	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1993	2446	1.042	1.012	1.215	1.048	1.022	0.990	1.002	1.032
1994	2766	1.041	1.250	1.315	1.116	1.031	1.035	1.033	1.088
1995	2968	1.046	1.264	1.365	1.126	1.020	1.027	1.024	1.092
1996	3342	1.055	1.296	1.347	1.139	0.972	1.049	1.019	1.098
1997	3545	1.066	1.185	1.410	1.123	0.991	1.114	1.066	1.104
1998	3369	1.068	1.190	1.304	1.118	0.930	1.170	1.077	1.104
1999	2656	1.032	1.176	1.287	1.089	0.890	1.018	0.968	1.048
AAG		0.46%	2.34%	3.67%	1.22%	-1.65%	0.25%	-0.46%	0.67%
Ntot	23249								

[17] The sharp decrease in 1999 is remarkable but can be explained as follows. As mentioned before ANWB constructs user-cost estimates for new passenger cars based on information at the beginning of a year. This implies that the fuel consumption cost estimates for a given year are based on fuel prices of January 1. In the beginning of 1998 both petrol and diesel prices were relatively high compared with the annual averages; the opposite holds for 1999. This means that the 1998 (fuel consumption, operating and total) cost estimates probably

increased slightly (*FUELC*; *AAG* = 0.25%), which is the joint effect of a substantial increase of fuel prices (see Table 6 below) and a considerable increase of fuel economy. This final result is demonstrated in Table 4 where the developments of car prices and some other characteristics of new passenger cars in the Netherlands are given. As shown there the average fuel consumption monotonically has decreased from 8.1 l/100km in 1992 to 7.1 l/100km in 1999, implying a decrease (improvement) of more than 12% (*L100KM*; *AAG* = −1.82%).

Both car insurance premium (*INSUR*) and road tax (*ROTAX*) have increased considerably according to the ANWB estimates during the 1992-1999 period[18] (*AAG* = 2.34% and *AAG* = 3.67%, respectively), although the highest index values occurred in 1996-1997 (1.296 and 1.410, respectively) and these costs have moved downward since then. The increase in insurance premium is partly due to the increase of average car weights (*WGHTKG*; *AAG* = 0.65%) and also partly to the increase of consumer prices (*PDFL*; *AAG* = 0.37%) of new cars (see Table 4).

A further conclusion from Table 3 is that costs of depreciation have also increased over the observation period, but not as extreme as the other fixed cost components (*DEPRE*; *AAG* = 0.46%). The average annual depreciation costs almost monotonically increase unto 1998 (index value 1.068) and then fall to a level that is 3.2% higher than the 1992 level. The development of average annual

Table 4 - Developments of some characteristics of new passenger cars, 1992-1999

Year	*N*	*PDFL*	*KMPYR*	*LIFEYR*	*L100KM*	*WGHTKG*
Level						
1992	2157	33641	17853	4.26	8.1	976
1993	2446	34009	17803	4.26	7.9	979
1994	2766	34992	17927	4.26	7.8	996
1995	2968	35486	18040	4.25	7.8	1010
1996	3342	35017	17969	4.26	7.6	1019
1997	3545	35163	18028	4.26	7.5	1027
1998	3369	35108	18200	4.25	7.3	1028
1999	2656	34526	18111	4.26	7.1	1022
Index (1992= 100)						
1992	2157	1.000	1.000	1.000	1.000	1.000
1993	2446	1.011	0.997	1.001	0.974	1.002
1994	2766	1.040	1.004	0.999	0.965	1.021
1995	2968	1.055	1.010	0.999	0.963	1.034
1996	3342	1.041	1.006	1.001	0.945	1.044
1997	3545	1.045	1.010	1.000	0.929	1.052
1998	3369	1.044	1.019	0.999	0.904	1.053
1999	2656	1.026	1.014	1.001	0.879	1.046
AAG		0.37%	0.21%	0.02%	-1.82%	0.65%
Ntot	23249					

depreciation costs does not substantially differ from the development of new car prices: comparing column *DEPRE* in Table 3 with column *PDFL* in Table 4 it appears that the maximum difference in index values occurs in 1993 (3.1 percentage points) and the final difference is 0.6 percentage points. Average annual growth is slightly higher in case of depreciation costs (0.46% vs. 0.37%).

are somewhat upward biased, whereas the corresponding 1999 figures may slightly underestimate the real user costs.

[18] It should be noted that the road tax component of user costs is estimated by ANWB for the 'most expensive' region in the Netherlands (Drenthe). Therefore, the road tax levels in Table 3 slightly overestimate the nationwide average annual road tax levels.

Both the average standard yearly kilometrage *(KMPYR)* and the average lifespan *(LIFEYR)* appear to be relatively stable according to Table 4: on the average a new car drives 18,000 km per year and is sold after 4 years and 3 months.[19] Combining the lifespan information with the depreciation cost figures (*DEPRE*), an estimate can be given of the total devaluation of a new car at its first change of ownership (i.e. the moment of first sale at the second hand market). This value varies from (5476×4.26 ≅) DFL 23,328 in 1992 to (5849×4.25 ≅) DFL 24,858 in 1998, which amounts to 70% of the original new price.

The results in Table 3 have been obtained using the *annual* user-cost index $IAUC_t$ in (2). Table 5 shows the results for the *unit* user-cost index $IUUC_t$. The developments of the user-costs-per-kilometer do not substantially differ from the annual user-cost developments. This is probably caused by the stable pattern of the average standard yearly kilometrages (*KMPYR*) in Table 4; cf. (1) and (2). The average annual growth values in Table 5 are generally slightly below the corresponding values in Table 3. The absolute difference between the average *annual* total user-cost (*TOTAL*) index and the corresponding *unit* index amounts to 0.8 percentage point in the final year 1999.

The unit depreciation cost figures in Table 5 can also be used to produce an estimate of the total devaluation of a new car at the moment of first sale at the second hand market. The estimate is now obtained as the product of (average) unit depreciation costs, yearly kilometrage and lifespan. The results are (of course) very similar to the results already found. For example, based on the 1992 information we find (0.303×17853×4.26 ≅) DFL 23,044 and in 1998 the devaluation estimate becomes (0.318×18200×4.25 ≅) DFL 24,597; the unit user-cost based estimates are about DFL 300 lower than the annual user-cost based ones.

Table 5 - Developments of user-costs-per-kilometer of new passenger cars, 1992-1999

		Fixed costs				*Operating costs*			*Total costs*
Year	*N*	*DEPRE*	*INSUR*	*ROTAX*	*TOTAL*	*MAINT*	*FUELC*	*TOTAL*	*TOTAL*
Level (ct per km)									
1992	2157	30.3	11.9	3.5	45.6	9.1	14.6	23.7	69.4
1993	2446	31.5	12.0	4.3	47.9	9.3	14.4	23.8	71.6
1994	2766	31.4	14.9	4.6	50.9	9.4	15.0	24.3	75.2
1995	2968	31.3	15.0	4.8	51.1	9.2	14.9	24.1	75.1
1996	3342	31.7	15.5	4.7	51.9	8.8	15.3	24.1	76.0
1997	3545	32.0	14.1	4.9	51.0	9.0	16.1	25.1	76.1
1998	3369	31.8	14.1	4.4	50.3	8.3	16.9	25.3	75.6
1999	2656	30.9	14.0	4.4	49.3	8.0	14.9	22.9	72.1
Index (IUUC; 1992=100)									
1992	2157	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1993	2446	1.042	1.014	1.231	1.049	1.024	0.986	1.000	1.032
1994	2766	1.038	1.255	1.319	1.116	1.025	1.025	1.025	1.085
1995	2968	1.036	1.264	1.356	1.120	1.008	1.016	1.013	1.083
1996	3342	1.049	1.305	1.343	1.138	0.967	1.043	1.014	1.096
1997	3545	1.057	1.191	1.402	1.118	0.982	1.104	1.057	1.097
1998	3369	1.051	1.190	1.256	1.103	0.914	1.159	1.064	1.090
1999	2656	1.021	1.182	1.250	1.080	0.877	1.017	0.963	1.040
AAG		0.29%	2.42%	3.24%	1.11%	-1.86%	0.24%	-0.54%	0.56%
Ntot	23249								

[19] These *average* values are more or less in line with the values chosen by Schultz (2001) for *each* car separately. In his paper the lifespan of a new car was fixed at 4 years and the yearly kilometrage at 15,000 km.

The results for the CPI based user-cost indexes using (3) and (5) are shown in Table 6.[20] These results are compared with the annual user-cost indexes presented in Table 3. According to the CPI based estimates average annual total costs (*TOTAL*) have increased 10.6% (*AAG* = 1.45%) during the observation period. The index value in 1999 is 5.8 percentage points above the corresponding index value in Table 3 (1.048; *AAG* = 0.67%). In most observation years the CPI based index is above the car model based index *IAUC* (and also above *IUUC*). An exception occurs in 1994. It also happens in 1998, but as noted in Footnote 17 the car model based index in this year probably slightly overestimates the real user-cost level. On the other hand the absolute differences between CPI and car model based *TOTAL* index values are generally not too large. Apart from the difference in the final year (5.8 percentage points) where the car model based index probably slightly underestimates real total costs level, the maximum difference equals 1.3 percentage points (1996).

Looking at the fixed cost component it appears that both the CPI and the car model based *FIXED* index values have increased 8.9% over the entire observation period (*AAG* = 1.22%). This is more or less in line with Schultz (2001), where also minor differences were found in the final sample year between both fixed cost series. There are however larger discrepancies at the lowest aggregation level considered. Insurance costs (*INSUR*), for example, have increased 34.1% (*AAG* = 4.29%) according to CPI, whereas ANWB/RDC estimates show a 17.6% increase (*AAG* = 2.34%). The largest differences

Table 6 - CPI based user-cost indexes, 1992-1999

	Fixed costs				*Operating costs*			*Total costs*
Year	*DEPRE*	*INSUR*	*ROTAX*	*TOTAL*	*MAINT*	*FUELC*	*TOTAL*	*TOTAL*
Index (ICPI; 1992=100)								
1992	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1993	1.028	1.060	1.140	1.060	1.032	0.994	1.009	1.037
1994	1.037	1.200	1.167	1.109	1.062	1.047	1.053	1.084
1995	1.037	1.310	1.175	1.128	1.067	1.052	1.057	1.099
1996	1.016	1.336	1.175	1.122	1.065	1.108	1.094	1.111
1997	1.016	1.336	1.081	1.101	1.049	1.169	1.131	1.114
1998	1.016	1.336	1.011	1.085	1.049	1.156	1.122	1.100
1999	1.020	1.341	1.011	1.089	1.072	1.159	1.131	1.106
w90	2580	1410	1020	5010	1620	2470	4090	9100
w95	3325	1318	1350	5993	1363	2912	4275	10268
AAG	0.28%	4.29%	0.15%	1.22%	1.00%	2.13%	1.78%	1.45%

between both index series occur in the years 1997-1999. The opposite is found in case of road tax (*ROTAX*). Here the car model based index shows a much higher increase (*AAG* = 3.67%) over the observation period than the CPI based index (*AAG* = 0.15%). We don't know whether this is completely due to the use of the most expensive Dutch region for the ANWB road tax estimates (cf. Footnote 18), or whether also other causes of this difference may be found.

Looking at column *DEPRE* in Table 6 it appears that new car prices have increased 2.0% over the observation period (*AAG* = 0.28%) according to official CPI statistics. This is slightly less than the 2.6% found in Table 4 (*PDFL*) based on our ANWB/RDC data. Except for 1993 the official CPI index is always below the new car price index *PDFL*. The difference increases unto 3 percentage points in 1997 and 1998 and then drops to 0.6 percentage point in 1999.[21] The official new car price

[20] The column names in Table 6 correspond with those of Table 3 for comparison purposes. However, the index values presented in the columns concern the CPI commodity groups mentioned in Table 2. For example, *DEPRE* refers to purchases of new cars and *FUELC* to fuel prices.

[21] Also in Bode and Van Dalen (2001: Table 1) a comparison is made between the official CPI index and a weighted average of nominal car prices. As mentioned before (see Footnotes 7 and 9) in that paper the observation period starts already in 1990 and there is not a lower and upper bound on car prices. As a result of this, higher average annual growth rates and larger discrepancies between the two indexes are observed: the

index is always below the ANWB depreciation cost index (*DEPRE*) in Table 3, which has a value of 1.032 in 1999 (*AAG* = 0.46%).

With respect to operating costs (*OPERAT*) we observe large discrepancies between the CPI and car model based index. Table 6 shows a 13.1% increase (*AAG* = 1.78%), whereas in Table 3 a 3.2% decrease (*AAG* = –0.46%) was observed over the 1992-1999 period! CPI based user-cost indexes apparently overestimate real user-cost developments when ANWB/RDC figures are taken as a standard. This is in accordance with what might be expected: as mentioned before the CPI based method does not properly take into account the complementarity between inputs in producing the transportation service.[22] It is reflected in different developments of both the costs of maintenance and repairs (*MAINT*) and fuel consumption (*FUELC*) in Tables 3 and 6. The CPI based *MAINT* index values highly overestimate the car model based values: the 1999 values are 1.072 (*AAG* = 1.00%) in Table 6 vs. 0.890 (*AAG* = –1.65%) in Table 3. This result was already ascribed to the quality improvement of new passenger cars resulting in larger inter-overhaul times and lower maintenance costs. The car model based *FUELC* index values have increased slightly over the 1992-1999 period (*AAG* = 0.25%), but not as extreme as the CPI based estimates suggest (*AAG* = 2.13%).[23] This result was ascribed to a considerable increase of fuel economy.

4. Summary and conclusion

In this paper the user-cost approach is applied to the estimation of cost developments for private transportation in the Netherlands. The estimates are based on a large amount of ANWB/RDC information about prices, technical characteristics and sales of new cars sold in the Dutch passenger car market in the period 1992-1999. In addition, ANWB information on user costs is employed. Both annual user costs and user-costs-per-kilometer have been estimated for each car model and each year of observation. The user costs consist of fixed costs (depreciation, insurance premium and road tax) and operating costs (maintenance and fuel consumption). Car model based user-cost indexes that reflect the development of actual (annual and unit) user costs have been calculated and a comparison has been made with a CPI based user-cost index.

Both the car model and the CPI based index for total user costs on the average show an increase over the 1992-1999 period. The car model based annual user-cost index increases 4.8% (unit user-cost index 4.0%) over the entire period implying an average annual growth of 0.67% (unit user-cost index 0.56%). The index value in the final year, however, may be slightly biased downward due to the use of January 1 fuel prices. The CPI based index increases 10.6% (*AAG* = 1.45%).

Differences between car model and CPI based indexes are largely attributable to different developments of fixed and operating costs. Fixed costs have increased about 9%, both for the car model and the CPI based indexes. Large differences on the other hand are observed for operating costs. The CPI based operating costs index *in*creases more than 13% whereas the car model based index *de*creases about 3% during the observation period. The reduction of operating costs, and

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official index increases 11.2% (*AAG* = 1.2%) over the entire 1990-1999 period, whereas the nominal car price index increases even 23.5% (*AAG* = 2.4%). Calculating the development of nominal car prices for the 1992-1999 period based on these data we obtain a 7.1% price increase (*AAG* = 0.99%). The difference with the 2.6% increase found in Table 4 is entirely due to the presence of both relatively cheap and relatively expensive cars in the data used in the hedonic paper. See again Footnote 9. Apparently the removal of the relatively cheap and expensive cars in the present study yields a better approximation of the official CPI index.

[22] Schultz (2001) also found large differences between CPI based and user-cost based operating cost indexes, especially in case of Montréal, but in his paper the CPI estimates were *lower* than the 'real' user-cost estimates!

[23] In fact the CPI based *FUELC* index values represent the development of fuel *prices*, which have increased 15.9% over the entire period. We also compared the official fuel price pattern with the development of the January 1 fuel prices used by ANWB (cf. Footnote 17). The general pattern is quite similar, but as already mentioned in 1998 the January 1 index level is much higher than the 1998 yearly average (petrol 121.9 vs. 114.9 and diesel 136.1 vs. 126.5).

maintenance costs in particular (−11%; *AAG* = −1.65%), according to the car model based index, is a result of the 'continuous improvements of the durability of passenger cars', as expected in Bode and Van Dalen (2001: 16).

The results of this study generally conform those of Schultz (2001), who also found minor differences with respect to total *fixed* costs, but larger divergences for *operating* costs (especially for Montréal). However, contrary to Schultz' findings for operating costs our user-cost estimates show a *de*crease (instead of an *in*crease even *stronger* than average annual growth of the CPI based index for operating costs).

Some issues require further attention in future research. For instance, following the ANWB information each car model has been given a *fixed* yearly kilometrage and given this kilometrage a *uniform* distribution of lifespans over the range of possible lifespans is assumed. It is unclear how this assumption affects the estimates of user costs (developments). More information about driving behavior of private car owners is necessary in order to answer this question. Another issue is the nature of ANWB user-cost information. The estimates are based on price and cost information that is available at the *beginning* of a year. There is no reason to assume that this may lead to *systematic* biases, but further research is necessary. Some of the CPI commodity groups used in this study relate to both *new* and *used* (second hand) cars, as well as *other* vehicles, such as motors cycles. Use has been made of a relatively high level of aggregation of CPI groups, especially in case of the 'old' situation before 1995. Also here further research at a more disaggregate level would be necessary to study the consequences for the CPI based user-cost index results.

Although these issues ask for some caution in drawing definite conclusions, the results of this study provide empirical support for the idea that application of the user-cost principle leads to different estimates of cost developments for private transportation than the current CPI method

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