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Car Age, Taxation, Scrappage Premiums and the ELV Directive

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Abstract

A "chain of replacement" model is used to examine the effects of automobile taxes and of a scrappage premium on the life length of cars, and on the size of the car fleet. The predictions of the model are tested on data on the scrappage of cars in Sweden 1989-2002. The theoretical model predicts that increased taxes on the purchase of cars should increase the life length of cars, and reduce the number of cars. A scrappage premium would have the opposite effects. Changes in periodic taxes would have no effect on the life length of automobiles, but would reduce the size of the car stock. The econometric analysis indicates, however, that the effects both on the life-length of cars, and on the size of the car parc are small. On the basis of the conclusions from the theoretical and the empirical analysis, the possible implications of the European Union's Directive 2000/53/EC on end-of life vehicles (ELV) are discussed.

JEL: H29, L62, Q48

Keywords: taxes, automobiles, accelerated vehicle retirement programs, scrappage, ELV Directive

1 Introduction

Automobiles causes environmental problems when they are built, when they are used, and when they are disposed off. Policies that reduce the negative environmental impact from an automobile during one part of its life-cycle may increase the environmental harm caused during other parts of this life-cycle. An example of this has to do with changes in the life-length of automobiles. On the one hand, the pollution connected to the production of new cars, and the disposal of old cars, will be smaller the longer each car is used. On the other hand, new cars pollute considerably less than old cars. Per distance driven, a gasoline powered automobile from 1996 emits less than half as much as does a 1988 automobile, in respect of all but two of the fourteen most important emission components.[15] In addition, emissions from a given car may increase with its age as pollution reduction equipment wears down, and the general condition of the car deteriorates. Thus, a higher turn-over rate of the automobile parc may reduce average emissions from cars in use. New cars are also generally much safer for the driver and the passengers.

The present paper presents a theoretical framework to analyze how various policies will affect the life-length of automobiles, as well as on the size of the automobile parc. An empirical analysis is then performed of the Swedish system of "scrappage premiums". Under this system, a fee is charged on all new automobiles, which is repaid when the car is scrapped. Thus, the system may be viewed as a deposit-refund system.

This system may provide lessons with a bearing on the European Union's Directive 2000/53/EC on end-of life vehicles (ELV), which aims to minimize and control the environmental hazards from scrapped automobile. At the same time, the Directive is likely to make the cost of disposing of used automobiles higher than it would otherwise be. Certainly, the ELV directive demands that the "Member States should ensure that the last holder and/or owner can deliver the end-of life vehicle to an authorized treatment facility without any cost as a result of the vehicle having no or a negative, market value." Also, the Directive introduces so called "extended producer responsibility" for automobiles by requiring that "producers meet all, or a significant part of, the cost of implementing these measures." However, since the purpose of the directive is to further "the fundamental principle that waste should be reused and recycled", i.e. stimulate recycling beyond what is privately profitable, it will lead to added costs. These costs will show up somewhere, and it is unreasonable to assume that all costs will in the end be

borne by the producers. Inevitably, a considerable fraction of the cost will have to be covered by price increases of cars, or in some other fashion that increases the cost of owning a car. As a consequence, it is conceivable that car-owners will defer the time at which they buy a new car and dispose of their old vehicle. To what extent this will happen will partly depend on how the Directive is implemented by the Member States, which is still an open question. The Directive give quite a wide scope for the Member States to adopt different regulatory options. Even though the Directive requires implementation of "free take-back" of ELV:s for all new vehicles sold from July 1, 2002, this provision has not been implemented in all Member States. In fact, according to the European Automobile Manufacturers Association only in four countries, Germany, the Netherlands, Sweden and Norway (which, though not a EU member, is bound by the EES Treaty to follow the Directive), are "free take-back" offered to owners of ELV:s. In Denmark, it costs money to dispose of an ELV, but owners are offered an economic compensation if the vehicle is disposed off properly. While most Member States are preparing legislation, the implementation process is far from complete.[8]

It appears that three basic approaches have been taken to the "free take-back" requirement. One approach, which resembles the Swedish scrappage premium system, is to collect a fee from car owners, which is used to subsidize treatment of ELV:s. In the Netherlands, as in Sweden, this fee is collected from the first owner of the car. In Denmark, the system is financed via an annual payment which is added to the liability insurance premium. The second approach, under consideration in France, is to use voluntary agreements with the automobile industry, and minimize government intervention. How such a system would work in practice is unclear. Finally, one approach, which has been proposed in the UK, is to take a "company-by-company" approach, and assign responsibility for recovery of vehicles to each individual producer or importer. Under such a system, different producers could adopt different models to reach the targets.[8],[9]

The Swedish scrappage premium system, which has been in operation since 1976, has dual objectives. The first, and at the outset the only, objective is to provide an incentive for car owners to dispose of ELV:s properly. At the time of the introduction of the system, cars disposed in woods and by the side of roads was a large and growing concern. The second objective, which was first introduced when the system was altered in 1992, was to reduce the life length of automobiles. At that time, the scrappage premium was differentiated, so that cars that had passed the compulsory vehicle inspection

received a higher premium when scrapped.

Certainly, policies designed to reduce the life-length of automobiles have been tried in other countries than Sweden. However, most such "early retirement programs", "accelerated scrappage schemes" or "accelerated vehicle retirement programs" are of limited duration, and involve the payment of a fixed sum of money, a scrappage premium, to car owners who decide to scrap their cars under the duration of the program. This premium is usually not paid for all cars but only under certain conditions. Such conditions might include that the car should be above a given age. In many cases, the premium is tied to the purchase of a new car. This has been the case with the accelerated scrappage schemes employed in France, Greece, Italy, Spain and Ireland, but not with the Danish and Norwegian schemes. An additional motive behind schemes where the premium is tied to the purchase of a new car has been to stimulate the automobile industry. In France, this was in fact the main motive for the so called "Balladurette" and "Juppette" programs.[1] All European accelerated vehicle retirement programs have been government financed, even though the automobile industry has sometimes provided additional incentives to consumers who buy new cars. [5],[19]

In the United States, accelerated vehicle retirement programs (AVRP:s) have been promoted by the EPA as a means for state and local government and industry to meet requirements under the Clean Air Act.[10] In Delaware, an AVRP was implemented by the U.S. Generating Company to offset an increase in hydrocarbon emissions caused by transports to a new plant. [3] Under a consent decree, General Motors has agreed to implement and finance AVRP:s in Southern California and in Phoenix/Maricopa County in Arizona.[12]

Several papers analyze the costs and benefits of such policies, or policy proposals, or examine the factors determining participation in a scrappage program, by the use of simulation techniques or through econometric analysis. (See e.g. [2], [3] and [11].) Alberini, Harrington and McConnell [3] also present a theoretical model of the decision to participate in a vehicle scrappage program. Another approach to the effects of policy on the life length of vehicles is presented by Innes.[13] He derives an expression for the optimal periodic tax (road tax) for cars of different "vintages" when external costs vary systematically between these, and shows that a scrappage premium that declines with the age of the car may be an alternative to a road tax which

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[1] Adda and Cooper[1] analyze these programs.

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increases with the age of the car. Bohm [7] offers a thorough theoretical and empirical analysis of deposit-refund systems.

Unlike previous papers that deal with automobile scrappage, the theoretical part of this paper does not focus on the scrappage decision per se. Rather, we model how the optimal life length of automobiles and the size of the car fleet is determined by the combination of taxation and a scrappage premium. This allows us to analyze a broader range of policy issues, and also to get some insights into the likely long-term effects on emissions from accelerated scrappage programs. The model presented in Section 2 assumes an infinite horizon model with certainty, and interprets the problem as a "chain of replacement" problem. (See e.g. Massé[17].) By allowing individuals to differ in their valuation of car ownership, the consumers' decisions on whether or not to be car-owners can be studied within the model. Also, since we do not foucs on temporary programs, such as AVRP:s, the lessons learned should be relevant to understand the implications of the ELV Directive.

An econometric analysis of the Swedish scrappage premium system is performed. We analyze the effects of changes of the scrappage premium on the number of cars that are scrapped and sold as well as on the stock of automobiles. The results indicate first, that the responses to changes are asymmetric, in the sense that the absolute values of the induced changes in the dependent variables are different for reductions and increases in the scrappage premiums. Secondly, while the number of cars sold and scrapped are affected by changes in the scrappage premium in the short run, there is no discernible effect on the number of cars and the life length of cars. Thus, we find no evidence indicating that the Swedish scrappage premium system has been successful in reducing the life length of automobiles, which has been one of the stated objectives of the policy.

It can be argued that the latter conclusion, together with the theoretical analysis, provides a general lesson for analyzes of the car market. It seems that automobiles sales is really not a good measure of the effects of changes to prices and other variables, since sales will "over react". A fall in prices will lead to an increase in the optimal size of the automobile parc. To adjust to the new optimal level, car sales may temporarily increase drastically, even when the underlying change is small. Also, temporary changes that induce many car owners to scrap their cars, may induce a drastic, but temporary, increase in car sales. To avoid such pitfalls, it may be preferable to study how the car stock changes, instead of analyzing changes to sales.

The remainder of the paper is organized as follows. In section 2, a the-

oretical model, based on a chain-of-replacement model is presented, and the implications of the model are analyzed. In particular, we discuss how changes in various taxes will effect the life-length of vehicles and the optimal size of the car parc. Effects of temporary and permanent changes are treated. In section 3, an empirical analysis of the Swedish scrappage premium system is presented. In section 4 we discuss the policy implications from the theoretical and empirical results. In particular, we consider implications for the implementation of the ELV Directive. Section 5 concludes.

2   A theoretical model

2.1   The chain-of-replacement problem

An automobile is a durable good. Thus, the utility to an individual from a car will depend on the benefit and cost streams from using the car over its entire life. In fact, to analyze the consumer's decisions we also need to consider that when the car is disposed off, he will replace the car with a new car. Thus, we will first specify a chain-of-replacement model, and derive the first order condition for the optimal life length of automobiles.[2]   We then consider factors that will determine the size of the car park.

Consider an infinitely lived individual j who derives the following instantaneous utility from owning an automobile of age t:

$$u_j(t) = \alpha_j + s(\zeta; t) + L \tag{1}$$

where $s(\zeta; t) + L$ is the net benefit from a car of age t, and α_j is a taste parameter, which is constant over the age of the car, but varies over individuals. ζ is a parameter determining the rate at which the utility from owning the car falls with the age of the car. ζ may thus be viewed as a depreciation parameter. We will assume that $\partial s / \partial t < 0$, and that $\partial s / \partial \zeta < 0$.

Assume further that the (exogenous and constant) price of a new car is p, where p may include a tax on the sale of cars. Also, in the case with extended producer responsibility, the price may have to include the costs for the automobile producer of taking care of the car once it is scrapped. When the automobile is scrapped, the owner incurs a cost, and may receive

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[2]The problem is formally identical to the problem of determining the optimal rotation period of an even aged forest stand. Löfgren[16] give an exposition on the debate on the correct procedure to detemine the optimal rotation period.

a scrappage premium, with the net value R. R may thus be smaller or greater than zero. However, we will throughout assume that the cost of scrapping a car is zero to the car owner, and that R is a non-negative scrappage premium.

Assume a simple utility function, which is linear in income. The net present value, to individual j, of the utility from owning a car that is bought when it is 0 years old, and kept until it is T years old, may then be written as:

$$B_j(T) = -p + \int_0^T e^{-\rho t} \left[\alpha_j + s(\zeta; t) + L\right] dt + e^{-\rho T} R \tag{2}$$

where $\rho \in \,]0, 1[$ is the constant discount rate.

Since the decision problem will be identical every time the car is replaced, we can immediately conclude that the replacement time must always be the same. We also recognize that the total net present value of utility to the consumer from being a car owner will be the same, every time a replacement takes place. Thus, we may write the total present value utility from being a car owner as a function of T, as[17]:

$$U_j(T) = B_j(T) + e^{-\rho T} U_j(T) \tag{3}$$
$$\Rightarrow$$
$$U_j(T) = \frac{1}{1 - e^{-\rho T}} B_j(T) \tag{4}$$

This expression defines a "chain of replacement" problem.

The consumer's maximization problem, assuming an interior solution, will thus be:

$$\max_T U_j(T) = \frac{1}{1 - e^{-\rho T}} B_j(T) \tag{5}$$

yielding the first order condition:

$$\frac{\partial U_j(T)}{\partial T} = -\rho \frac{e^{-\rho T}}{\left(1 - e^{-\rho T}\right)^2} B_j(T) +$$
$$+ \frac{e^{-\rho T}}{1 - e^{-\rho T}} \left[\alpha_j + s(\zeta; T) + L - \rho R\right] = 0 \tag{6}$$

which, using (4), may be rewritten as:

$$\rho \left[U_j(T) + R\right] = \alpha_j + s(\zeta; T) + L \tag{7}$$

Notice that the left hand side of this expression is the opportunity cost of waiting with the replacement of the automobile, and that the right hand side

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is the instantaneous utility of car ownership at time T. Thus, the optimal replacement time T^* will be set such as to equalize these two.

If we decompose the integral in (2), solve the parts containing the constants L and α_j, and then use (4) to separate out $[\alpha_j + L]/\rho$ from $U_j(T)$, we see that α_j and L cancel out in the first order condition, and that we may write the first order condition as follows:

$$\frac{\rho}{1 - e^{-\rho T}}\left(p - R - \int_0^T e^{-\rho t}s(\zeta;t)dt\right) + s(\zeta;T) = 0 \qquad (8)$$

The optimal replacement time will thus be independent of the individual specific effect, α_j. Also, we can conclude that a tax, such as a road tax, that is the same regardless of the age of the car, will not effect the optimal life-length of the car. (Unless, of course, it is differentiated on the basis of the age of the car.) This is not surprising since both α_j and L are additive in the individual's utility function and are independent of how often the individual buys a new car. As long as the consumer is a car owner, he will receive the benefit stream $\alpha_j + L$.

Since the first order condition must hold identically, we may totally differentiate expression (8) to see how the optimal replacement time will be affected by policy changes, or other changes, that affect the price of the car, p, the scrappage premium, R, the depreciation parameter, ζ, or the discount rate, ρ. Applying the implicit function theorem, we obtain:

$$\frac{dT}{d\rho} = \left(\begin{array}{c} -\frac{1 - e^{-\rho T} - \rho T e^{-\rho T}}{\rho(1 - e^{-\rho T})}s(\zeta;t) - \\ -\frac{\rho}{1 - e^{-\rho T}}\int_0^T te^{-\rho t}s(\zeta;t)\ dt \end{array}\right)\frac{1}{-s'(\zeta;T)} \qquad (9a)$$

$$\frac{dT}{d\zeta} = \left(\frac{\partial s(\zeta;T)}{\partial\zeta} - \frac{\rho}{1 - e^{-\rho T}}\int_0^T e^{-\rho t}\frac{\partial s(\zeta;t)}{\partial\zeta}dt\right)\frac{1}{-s'(\zeta;T)} \qquad (9b)$$

$$\frac{dT}{dp} = \frac{\rho}{1 - e^{-\rho T}}\frac{1}{-s'(\zeta;T)} \qquad (9c)$$

$$\frac{dT}{dR} = -\frac{\rho}{1 - e^{-\rho T}}\frac{1}{-s'(\zeta;T)} \qquad (9d)$$

where we have used the first order condition, (8), to obtain expression (9a). By assumption, $s'(\zeta;T) < 0$. The optimal life-length of a car will decrease if the discount rate increases, since (9a) will always be negative.

Expression (9b) tells us what happens if the depreciation parameter changes. By assumption $\partial s/\partial\zeta < 0$. Thus, the first term is negative, and the second

term is positive, which means that the sum may be positive or negative. Whether an increase in ζ will prolong or shorten the life of automobiles will depend on the shape of the function $s(\zeta; t)$. If a change in ζ mainly affects the rate of decrease in the value of the car when the age of the car approaches T, then the first term will be relatively large in absolute value. If, on the other hand, ζ mainly affects the rate of decrease in the value of the car in the beginning of the car's life, the second term will dominate. Suppose that ζ is a measure of the stringency of a compulsory automobile inspection system. This would primarily affect old cars, and would thus be likely to reduce T. If, on the other hand, ζ measurs the premium consumers put on owning a new car, then changes in this parameter will mainly affect the second term.

From a policy point of view, it is perhaps most interesting to know the effect of taxes and of the scrappage premium. From the first order condition, it should be clear that changes in taxes that affect all automobiles similarly regardless of their age, such as a uniform road tax, will not affect the optimal life length of the automobile. From expressions (9c) and (9d), it should be clear that reduction of a tax on the sale of automobiles will have exactly the same effect as an increase by the same amount of the scrappage premium. The reason for this is that *given* that the consumer is a car owner, the scrappage premium will always be received at the same time as the registration tax is paid, since the consumer will always buy a new car when the old one is scrapped. Thus, with regard to the life length of automobiles, a positive permanent scrappage premium is exactly equivalent to a negative registration tax. Thus, a revenue neutral deposit-refund system, i.e. a system where the buyer of a car pays a sum which is refunded, with interest, when the car is scrapped, would reduce the life-length of automobiles.

We now turn to the issue of how the size of the car parc is determined. To do this, we first want to determine under which conditions a consumer will be a car owner. A consumer will own a car if the utility from doing so is larger than the utility from not owning a car. Let us normalize by setting the utility of not owning a car to zero. Thus, consumer j will be a car owner if:

$$U_j\left(T^*\right) \geq 0 \tag{10}$$

Now, define the "individual invariant" utility from being a car owner, by:

$$U(T) = \frac{1}{1 - e^{-\rho T}} \left[-p + \int_0^T e^{-\rho t} \left[s(\zeta; t) + L \right] dt + e^{-\rho T} R \right] \qquad (11)$$

$$\Rightarrow$$

$$U_j(T) = U(T) + \alpha_j / \rho \qquad (12)$$

$U(T)$ is thus the part of utility derived from being a car owner that is common to all individuals. To obtain the second expression, we use the same decomposition of expression (2) as above, solve the part containing α_j, and are then able to separate out $\left(1 - e^{-\rho T}\right) \cdot \alpha_j / \rho$ from the resulting expression. Note that the second right hand term of expression (12) is equal to the net present value of an eternal benefit stream with a value equal to the "taste factor" in the utility function.

Using (10) and (12) we can write the condition under which individual j will be a car owner as:

$$\alpha_j \geq -\rho U(T^*) \qquad (13)$$

To go from this expression to an expression for the size of the car park, we need to make some assumptions about the distribution of the taste parameter, α_j. First, assume that the economy is inhabited by a continuum of individuals, and normalize their number to one. Assume further that α_j is distributed over these individuals according to an integrable density function, $\psi[\alpha_j]$, such that $\int_a^b \psi[\alpha_j] d\alpha_j$ gives the proportion of individuals with a value of α_j between a and b. The number of car owners, as a function of the policy variables, can then be written:

$$n = 1 - \int_A^\infty \psi[\alpha_j] d\alpha_j \text{ where } A = -\rho U(T^*) \qquad (14a)$$

$$\Rightarrow$$

$$n = 1 - \Psi[-\rho U(T^*)] \qquad (14b)$$

where $\Psi[\alpha_j] = \int_{-\infty}^{\alpha_j} \psi[k] dk$ is the cumulative distribution of α_j. The expression in (14b) can then be used to analyze how policy changes will affect the

size of the car parc. Differentiating expression 14b yields:

$$\frac{dn}{d\rho} = -\psi A \left(\begin{array}{c} U\left(T^*\right) + \\ +\rho \left(\begin{array}{c} \frac{s(\zeta;T)}{\rho} + \frac{1}{1-e^{-\rho T}} \int_0^T t e^{-\rho t} s(\zeta;t)dt + \\ +\frac{T e^{-\rho T}\left(1-\rho T e^{-\rho T}-e^{-\rho T}\right)+\rho\left(1-e^{-\rho T}\right)^2}{\rho^2\left(1-e^{-\rho T}\right)^2}L \end{array} \right) \end{array} \right) \quad (15a)$$

$$\frac{dn}{d\zeta} = -\rho\psi A \cdot \frac{-\int_0^T e^{-\rho t}\frac{\partial s(\zeta;t)}{\partial \zeta}dt}{1-e^{-\rho T}} \quad (15b)$$

$$\frac{dn}{dp} = -\rho\psi A \cdot \frac{1}{1-e^{-\rho T}} \quad (15c)$$

$$\frac{dn}{dR} = \rho\psi A \cdot \frac{e^{-\rho T}}{1-e^{-\rho T}} \quad (15d)$$

$$\frac{dn}{dL} = \psi A \quad (15e)$$

Thus, we see that an increase in the discount rate reduces the size of the car parc, as does an increase in the depreciation parameter ζ. Thus, while the effect of changes in the depreciation rate of a car on the optimal life length of a car will depend on the shape of the function $s(\zeta;t)$, the effect on the size of the number of cars in the economy will be unambiguously negative.

It is also clear that it is now the changes to the price and equivalent changes to the net present value at the time of the purchase of the automobile of the scrappage premium that have equivalent effects. Thus, while a revenue neutral deposit-refund system would have an effect on the optimal life-length of automobiles, it would not affect the size of the car parc.

From (15e), it is clear that changes that affect the value of owning an automobile, such as a road tax, will affect the size of the car parc. The effects of any policy change on the size of the car park will be larger, the larger is the number of people who are close to being indifferent between being car owners and not being car owners, i.e. the denser the distribution ψ is around $-\rho U\left(T^*\right)$.

2.2 Permanent changes

This far, we have considered changes to the optimal life-length of automobiles, and to the optimal size of the car park. However, we cannot always expect the car parc to change instantaneously as a response to changes in the optimal level of these two variables.

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If the optimal life length of automobiles decrease, say from T^* to $T^{**} < T^*$, then the adjustment to the new equilibrium may take place at once, simply by replacing all automobiles older than T^{**}. If, on the other hand, the optimal life length increases, so that $T^{**} > T^*$, the adjustment cannot be instantaneous, since automobiles older than T^* have already been scrapped, and cannot be "unscrapped". Thus, no cars will be taken out of use during a period of $T^{**} - T^*$, i.e. until the oldest cars in the car parc have reached the new optimal life-length. Since, in the model, the only people who buy new cars are those who have just scrapped their old car, no new cars will be sold during this period, unless the optimal size of the car parc has also changed.

If the optimal size of the car parc increases, say from n to $n' > n$, this implies that the threshold, A from expression (13), has fallen, say from A to $A' < A$, and that some individuals, whose car preference, α_j, is such that $A' \leq \alpha_j < A$, will now become automobile owners. Since we have implicitly assumed that supply is infinitely elastic, these individuals will immediately buy cars. Naturally, in real life we would not expect the transition to a larger car parc to be literally instantaneous, but would expect lags, and effects on the supply side. However, it is reasonable to believe that adjustment would be rather rapid.

Consider instead a fall in the optimal size of the car parc, say from n to $n'' < n$, or equivalently, a rise of the threshold, A, to $A'' > A$. Consider an individual j whose car preference α_j, is such that $A \leq \alpha_j < A''$, and who is thus a car owner previous to the change in A. It is clear that he will not choose to buy a new car once he discards of his old car. Suppose however, that he owns a car of age $v_j < T^*$. Then this car may still have a value to him. Assuming that there is no second hand market for cars, the value of the car, to individual j, will be:

$$q_j\left(\alpha_j, v_j\right) = \int_{v_j}^{\overline{T}_j^*} e^{-\rho(t-v_j)} \left[\alpha_j + s(\zeta; t) + L\right] dt + e^{-\rho\left(\overline{T}_j^* - v_j\right)} R \qquad (16)$$

where $\overline{T}_j^*$ is the optimal age of disposing of the car. It is straight forward to show that $\overline{T}_j^* < T^*$. Also, it may be the case that the optimal $\overline{T}_j^* \leq v_j$, in which case $q_j = R$, and the optimal choice of individual j, in the absence of a second hand market, is to scrap the car immediately. However, in the case that $\overline{T}_j^* > v_j$, we would expect individual j to keep the car for a period $\overline{T}_j^* - v_j$ after the change in A. Since all individuals with α:s such that $A \leq \alpha < A$ will have cars of different ages, and will also choose different levels for $\overline{T}^*$, the

time it will take for the car parc to adjust to the new level will depend on the maximum value for $\overline{T}_j^* - v_j$ over all individuals with an $\alpha_j : A \leq \alpha_j < A''$.

From expression (16), it should be clear that all changes to the optimal size of the car parc will not have an equal effect on the rate of adjustment. We know from expressions (15c) and (15e) that the change to n^* from a increase in p by $\frac{1}{1-e^{-\rho T}}$ will be equivalent to a reduction in L by 1. However, the rate of adjustment will be higher if L changes, since this will result in a lower $\overline{T}_j^*$.

Clearly, it is unreasonable to rule out the existence of a second hand market in cars. To approach the issue of what we may expect if used cars can be traded, consider an individual k with an $\alpha_k \geq A''$, i.e. an individual who will continue to be a car owner, and whose old car has just reached T^*. The price he would be willing to pay for a car of age v_j will be determined by the following equation:

$$U_k\left(T^*\right) = -q_k\left(v_j\right) + \int_{v_j}^{T^*} e^{-r(t-v_j)} \left[\alpha_k + s(\zeta;t) + L\right] dt + e^{-r(T^*-v_j)} \left[R + U_k\left(T^*\right)\right]$$

$$\Leftrightarrow$$

$$q_k\left(v_j\right) = \int_{v_j}^{T^*} e^{-r(t-v_j)} \left[s(\zeta;t) + L\right] dt + e^{-r(T^*-v_j)} R - \left(1 - e^{-r(T^*-v_j)}\right) U\left(T^*\right)$$

$$(17)$$

In other words, the highest price he would be willing to pay for a car of age v_j is the value that equates his utility from buying this car to his utility from buying a new car. The first term of the expression for the price is the utility from owning a car from age v_j until T^* and the second term, which will be negative, is the foregone utility from owning an old, instead of a new car. Note that we have integrated out the individual specific effect, α_k to arrive at the second expression, justifying the exclusion of α_k as an argument.

It is straight forward to show that $q_k\left(v_j\right) > q_j\left(\alpha_j, v_j\right)$ for $\alpha_j < A''$. Thus, there should be some intermediate price at which trade could take place. As long as there are car-owners whose $\alpha < A''$, we should expect that those whose $\alpha \geq A''$ and whose cars reach T^* would buy used cars from these car owners, instead of buying new cars. This implies that no car sales will take place until the car parc has been reduced to its optimal size, and that the transition to a smaller car parc will be more rapid than if no second hand trade in cars existed. In fact, we know that the longest it could take is the time it would have taken to sell $n'' - n$ cars.

2.3 The effect of transitory changes

This far, we have only considered permanent changes to policy. However, some policy changes have a limited, and known, duration. This is the case, for example, with the accelerated vehicle retirement programs mentioned in the introduction. Under the assumptions of the model, all cars with a market value lower than the temporary scrappage premium will immediately be scrapped. Thus, such a premium will lead to the accelerated scrappage of the oldest cars in the car park, since these will have the lowest market value. Since the premium is, by construction, a temporary measure, it can have no effect on the size of the car park. Thus, all scrapped cars will instantly be replaced by new cars. Similarly, the premium will not have any effect on the optimal life length of automobiles. Therefore, after the temporary scrappage premium has been abolished, and until the oldest cars that were not scrapped under the accelerated scrappage program reach their optimal life length, no cars will be scrapped. Also, unless the premium is introduced without warning, some car owners will delay scrapping their vehicles.

To establish these claims, we first want to determine what the market price will be for an automobile of a given age. The lowest price at which a consumer would be willing to give up a car of age v would be a price $p(v)$ that equates his utility from keeping the car until it reaches age T^*, and his utility from switching cars immediately and receiving $p(v)$. Thus, the market price of a car of age v must be such that:

$$q(v) + U_j(T) =$$
$$= \int_v^T e^{-\rho(t-v_j)} \left[\alpha_j + s(\zeta;t) + L\right] dt + e^{-\rho(T-v)} \left(R + U_j(T)\right)$$

$$\Rightarrow$$

$$q(v) = \int_v^T e^{-\rho(t-v)} \left[s(\zeta;t) + L\right] dt + e^{-\rho(T-v)} R - \left(1 - e^{-\rho(T-v)}\right) U(T) \quad (18)$$

which is identical to expression (17) except that we have no index denoting individuals on q and v. The reason for this is that, while the value to different consumers was different when we discussed policy changes that affected the equilibrium levels of n and T, the value of a car of age v will be the same to all consumers in the present case.

This price will thus constitute the market price of an automobile of age v. (Since all consumers have the same valuation, there will however be no

trade in used cars.) The first term is equal to the net present value of the "individual invariant" utility from the car during the remainder of its life, while the second term reflects the distance in time until the car will be replaced. It is easy to verify that $q(0) = p$ and that $q(T^*) = 0$.

Suppose, then, that a temporary scrappage premium equal to $\overline{R}$ is paid to all car owners who decide to scrap their cars. Obviously, all cars with a market price lower than this amount will be scrapped. Car owners who scrap their cars will immediately buy new cars, since by assumption, the premium is only temporary and thus does not affect the inequality in (10), which decides whether or not an individual consumer will be a car owner. The size of the car stock will be unaltered. By the same reasoning, so will the optimal life length of automobiles.

Since the market price of an automobile, (18), will be strictly decreasing in the age of the vehicle,[3] we may use the inverse of the price function to define:

$$v(q) = q^{-1}(v) \tag{19}$$

The temporary scrappage premium will thus lead to the scrappage of all cars older than $v(\overline{R})$. It should be noted that all these cars would have been scrapped anyway when they reached age T^*. Thus the scrappage premium will reduce the age of the scrapped vehicles by between 0 years, for cars that would have been scrapped anyway, at the time the program is introduced, and $T^* - v(\overline{R})$ years. It should also be noted that in this model, no new cars would be bought during a time period after the scrappage program of $T^* - v(\overline{R})$ years, since all cars that would have been scrapped during that period have already been replaced by newer automobiles. Obviously, the number of automobiles that are scrapped will depend on the age distribution of the car stock.

The reasoning in this section is similar to that of Alberini, Harrington and McConnell.[3] However, they do not address one issue, which is that a scrappage program usually cannot be introduced as a complete surprise. Rather, it will be known to automobile owners well in advance. Thus, they may either wait with buying a new car, or buy a new car but refrain from scrapping their old car until they may receive the scrappage premium. In fact, during the latter half of 1975, before the Swedish scrappage premium was first introduced, on the 1 January 1976, the scrapping of cars declined, thus

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[3]The reader may verify this by taking the first derivative of expression (18), inserting the first order condition, (7), and then noting that, by assumption, $s'(t) < 0$.

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indicating that some car owners waited to scrap their cars until they could receive the premium.[7] A similar effect was seen in Denmark. In 1993, the year before Denmark implemented an accelerated vehicle scrappage program, the number of scrapped cars declined dramatically. In 1993, only 8 000 cars were scrapped, which may be compared with the average over the years 1985-1995 which was 93 000 cars.[4]

To illustrate why some car owners may delay scrapping their automobiles, we first note that if there is no cost involved in keeping an old car, then no cars will be scrapped between the announcement of the premium and its implementation. People who would normally have scrapped their cars would just buy a new car and keep the old one until they could receive the premium. Usually, however, some cost would be incurred to store the car and to keep it in a sufficiently good condition for it to be eligible for the scrappage program. Assume that this cost is a constant periodic cost, m. In addition, scrappage programs usually require that the road tax should have been paid for the car. Thus, this cost may also have to be included in m. Thus, the cost of keeping the automobile for a period r, after it has reached age T^*, will be:

$$\int_{T^*}^{T^*+r} e^{-\rho[t-T^*]} m \, dt = \frac{1-e^{-\rho r}}{\rho} m \tag{20}$$

If this amount is smaller than the present value of the scrappage premium, then it will pay to wait. Thus, if it is known that an accelerated vehicle retirement program will be implemented at a given date in the future, a car owner who has a car that reaches its optimal life length r years before that date will delay scrapping it if:

$$e^{-\rho r}\overline{R} \geq \frac{1-e^{-\rho r}}{\rho} m_r \tag{21}$$

$$\Rightarrow$$

$$r \leq r^*\left(\overline{R}, m\right) = -\frac{1}{\rho}\ln\left(\frac{m}{\rho\overline{R}+m}\right) \tag{22}$$

where $r^*\left(\overline{R}, m\right)$ is thus the longest time any car owner will delay the scrapping of an automobile in order to obtain the scrappage premium.

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[4] The number of scrapped cars is calculated as the difference between the number of registered cars, and the change in the size of the car stock during a given year. Data were obtained from the 1989, 1995 and 1996 editions of *World Road Statistics*[20].

Naturally, the number of car owners who are going to wait to scrap their car will be larger, the larger is r^*. It is easy to verify that the number of delayed scrapped cars will be increasing in the scrappage premium, $\overline{R}$, and decreasing in the "storage cost", m. If the owner derives some benefits from owning the car, even after it is older than T^*, then this will also increase the number of delayed scrapped cars. The total number of delayed scrapped cars will, naturally, also depend on the age distribution of the car parc.

A temporary scrappage premium will thus have two effects. Firstly, some automobiles will be scrapped earlier then they would have been in the absence of the premium, and secondly, some scrapped cars will be delayed by car owners who would anyway have scrapped their cars in the period between the announcement of the scrappage program and its implementation. Since both of these effects depend on the age distribution of the car stock, we cannot say which effect will dominate. A temporary scrappage premium will have no effect on the optimal life length of automobiles, or on the size of the car stock.

3   An empirical illustration

The main purpose of the empirical section of this paper is to examine how the Swedish car parc has been affected by the Swedish scrappage premium system. We also include price indexes to attempt to account for changes in the cost of buying and owning automobiles. Since we are using time series data, we use a simple ARIMA specification for estimation. We begin by describing the details of the system, then the data, and how the model is specified, and finally the estimation results and interpretations of these.

3.1   The Swedish scrappage premium

The original purpose of the scrappage premium, when it was introduced in Sweden in 1976, was to give car owners an incentive to dispose of scrapped automobiles properly. Rusting hulks in woods, in parking lots, etc. were perceived as a serious problem. The system appears to have achieved this policy objective reasonably well in the beginning of its operation, but seems to have been less of a success later on. (See Bohm [7].)

Originally, the premium was SEK 300. This amount was increased to SEK 500 in 1988. From 1992, a higher premium, of SEK 1 500, was paid

for cars that had passed a vehicle inspection within 14 months before they were scrapped. The argument for introducing this higher premium was to reduce pollution by accelerating the scrappage of old automobiles.[6] In 1994, the condition for receiving the higher premium was made more stringent, by requiring that the car should have passed a vehicle inspection within 9 months before scrappage.[18] In 1998 the higher scrappage premium was abolished.

Since 1998 the system has been altered in several ways. First, when the differentiated scrappage premium was abolished, a law on extended producer responsibility for automobiles came into force, covering all cars registered from 1998 and onwards, except privately imported cars. The act requires that producers and professional importers of cars should provide for the last owner of ELV:s to dispose of the cars without cost, and that they should meet certain recycling targets. Secondly, in 2001 the "base" scrappage premium was raised to SEK 700 both for cars covered and not covered by the extended producer responsibility. The reason for also giving a premium for cars covered by the extended producer responsibility is that while the law requires that the owner should be able to dispose of an ELV free of charge, there may still be a cost to transport the car to the collection point. Thirdly, also in 2001, for cars not covered by the extended producer responsibility, a new differentiated premium was introduced, of SEK 1200 for cars between 7 and 16 years old, and SEK 1700 for cars 16 years old or above. Again, the motivation for the differentiated premium was to induce early retirement of automobiles.

Even though the nominal level of the scrappage premium has only been changed a few times, the real value has varied considerably due to inflation. Translated into 2002 currency, the scrappage premium in January 1980 was around SEK 850.[5] Before it was raised in April 1988, the real value had fallen to around SEK 485. After it was raised, the nominal premium was SEK 500, which in todays price level would correspond to SEK 780. Thus the increase in the premium was not enough to fully compensate for inflation since the beginning of the decade. The changes to the system, toghether with the variations caused by inflation, makes it possible to study the effects of the scrappage premium on the scrappage rate.

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[5]SEK 1 $\approx$ USD 0.12 $\approx$ EUR 0.11, as of February 2003.

3.2 The data and the empirical model

The theoretical model presented in Section 2 predicts that the scrappage premium should have a negative effect on the optimal life-length of automobiles, and a positive effect on the optimal size of the car stock. However, neither the optimal life-length of automobiles nor the optimal size of the car stock are directly observable. What we observe is the actual car stock, and the number of cars that are sold and scrapped. If the changes to the scrappage premium affects the car stock, we should be able to identify that effect by observing changes in the actual car stock. To deduce the effects on the life-length of cars, however, we need to analyze the two other variables. If the life-length of cars falls as a result of increases in the scrappage premium, we would expect both the number of cars scrapped and the sale of new cars to increase in tandem. Thus, we are going to use all of these three variables as dependent variables. Data on scrapped cars, registrations of new cars and of the car stock were obtained from Statistics Sweden.

The theoretical model indicates that the cost of buying and of owning and running cars, as well as the interest rate, will influence our variables. The first two of these were constructed from the consumer price indices for these two groups of goods. However, since the cost of buying a car is bound to be endogenous, we instrument for this variable, using the producer price index for the car industry. The indices were obtained from Statistics Sweden. Interest rates were obtained from the Bank of Sweden, and transformed to real interest rates using the 12-month-change in the consumer price index. We also include data on real GDP, to take account of changes to income.

Five different variables can to be used to describe the scrappage premium: one for the "base" premium, which is paid for any properly scrapped automobile; one for the scrappage premium paid to automobiles that had passed vehicle inspection within 9 months before scrappage; one for the premium for cars that had passed inspection within 14 months before scrappage; one paid for cars between 7 and 16 years old and one for cars older than 16 years. However, since the latter two are perfectly collinear, both of these cannot be included in a regression. There is also severe multi-collinearity between the four remaining scrappage premium variables. Thus, in our regressions, we use two variables, one for the "base" premium, and one for the higher premium, ignoring the changing rules on which cars are eligible for this premium. Data on the scrappage premiums were obtained from the Swedish car producers' and importers' association. ("Motor Traffic in Sweden 2001".[18])

All time series are monthly data, except GDP, which is a quarterly series. Since there is a marked seasonal component in car sales, car scrappage and the stock of cars, these series were seasonally adjusted, using the ratio to moving average method. All monetary values were deflated using the CPI.

As pointed out above, we would expect the effect of changes to be asymmetric, in the sense that the actual car stock would adjust quicker to an increase in the optimal size of the car stock than to a decrease. Also, it would take longer for the car parc to adjust to an increase in the optimal life length of cars than to a decrease. To account for this, we include the absolute value of the scrappage premium variables. If the coefficients on a variable and on the absolute value of the same variable have the same sign, then this implies that a positive change to this variable has a larger effect than a negative change, and vice versa. Theory predicts that we should expect lags. This is accounted for by including lags of the scrappage premium variables, and by including autoregressive and moving average terms.

We ignore several complications. Among these are first, that we use a linear model for estimation, while we could have used a more "structural" specification, based on the theoretical predictions, and secondly, that we only include lags and absolute values of the scrappage premium variables, and not for the other variables. The justification for both of these simplifications is that a more elaborate specification would place a heavier demand on the data than the data set we use would stand for.

3.3 Estimation results

Dickey-Fuller tests were used to test for stationarity of all series. The size of the car stock, the price index for buying cars, and the GDP variable were integrated of the second order, and the rest of the series of the first order. Three models were estimated, with respectively, the first differences of car sales, the first difference of the number of cars scrapped and the second difference of the car stock as the dependent variables. It seems reasonable that the stock of cars should be integrated to a higher order than the two other variables, since the difference between sold cars and scrapped cars should in principle be equal to the change in the car stock.[6] The same explanatory variables are included in all equations. However, different AR

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[6]The difference between changes in the size of the car parc, on the one hand, and the difference between sold and scrapped cars, on the other hand, is due to reporting errors and "leakage", e.g. cars that are deregistred but not properly scrapped.

and MA terms were included to account for serial correlation in the data. These were selected on the basis of visual inspection of correlograms for the residuals. Estimation results are presented below in Tables 1 through 3.

Breusch's and Godfrey's Lagrange multiplier test was used to test for serial correlation. (See e.g. Judge, et al.[14].) This is a test of the null hypothesis of no serial correlation among the residuals against the composite alternative hypothesis that the residuals follow a moving average or an autoregressive form of order P or less. The test was run setting $P = 12$. The null hypothesis of no serial correlation could not be rejected.[7] Still, we estimate the standard errors using the Newey-West procedure.

The indexes we include to account for the cost of buying and using a car have the predicted signs in all three regressions, i.e. they both have positive signs in the regression with the number of scrapped cars as the dependent variable, and negative signs in the two other regressions. However, only in one case is the sign significantly different from zero. (The coefficient on the cost of owning and running a car, in the regression with the car stock as the dependent variable, is significant at the 10 % level.) Thus, it seems that the indexes perform poorly. However, since our purpose is to analyze the effects of the scrappage premium, this is of limited importance. It is possible that the indexes are too rough measures, and should be replaced by e.g. the cost of an "average" car and the price of gasoline, or something of that nature. However, we do not explore this issue. The GDP variable has a positive and significant (10-percent level) coefficient only in the car-stock regression, and the interest rate variable is nowhere significant.

Since we include both lagged values of the scrappage premium variables, and the absolute value of the premiums and of their lagged values, we are not primarily interested in the parameters themselves, but of linear combinations of these, in all, eight coefficients. To determine the impact of a positive change in one of the scrappage premium variables, we take the sum of the coefficients on the premium itself and on the absolute value of the premium, and to determine the impact of a negative change, we take the difference between the two coefficients. To determine what the total impact of a change is, we take the sum of the coefficients on the variable and the lagged variable. These linear combinations of parameters, for all the three estimated models are presented in table 4.

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[7]The F-statistics produced were, respectively, 1.57, 1.55 and 1.47, implying that we cannot reject the hypothesis of no autocorrelation at any usual level of significance.

/Tables 1-4 about here./

Let us first look at how the number of scrapped cars is affected by changes in the scrappage premium. All scrappage coefficients, except one, are significant at least at the 1% level of significance. (The coefficient on the lagged value of the "base" premium is not significant.) Looking at the various linear combinations of coefficients, we see that the effect of changes is asymmetric, in the sense that the magnitude of positive and negative changes differ. The total impact of an increase to the base premium is more than thirty times greater in absolute value than the impact of a decrease. The latter is not even significantly different from zero. The impact of an increase in the higher premium is about five times greater in absolute terms than the impact of a decrease. For both variables, the total impact is smaller than the direct impact of a change. Thus, a major part of the effect from changes in the scrappage premium is to delay or put forward some scrapped cars, but without any long term effects. All of this is consistent with our expectations. We also see that the total effect on the number of cars scrapped is larger for changes in the base premium than for changes in the extra premium.

The results from the regression on car sales show, again, that the reaction to changes in the scrappage premium is asymmetric. This time, however, it is when the premium falls that we get the largest changes in absolute terms, but only when we look at the same period effects and the lagged effects separately. If we consider the total effect of a change, i.e. the sum of contemporaneous and lagged variables, only an increase in the "extra" premium has an effect on sales that is significantly different from zero, while the only significant effect of changes to the base premium is that it shifts sales between periods. Interestingly, increases in the extra premium reduces sales, which is contrary to expectations. However, this may not be as strange as it seems. Since the extra scrappage premium is conditioned upon the age or the condition of the car it may be viewed as a change to the rate of depreciation of the car at the end of its life. In our model, it changes the shape of $s(\zeta; t)$ for values of t close to T^*. It is perhaps easiest to understand why that may be the case under the system as it works after the most recent changes. Under this system, cars that are older than 7 years receive a higher premium, and cars that are older than 16 years an even higher premium. Thus, if a car owner would have scrapped his car just before any of these break points, it will pay him to postpone scrapping the car. This will tend to increase the life-length of the car, since some car owners will have an incentive to postpone the scrapping of their car, but no car owners will have an incentive to bring

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forward scrapping their car. It is likely that especially the 16 year breakpoint is significant. Using a rough measure of the life-length of cars, it turns out to be almost exactly 16 years, and have been so since the middle of the 1990s. With the older system, where cars that had passed the mandatory vehicle inspection were eligible for a higher premium, it is slightly more complicated to see how this happens, but the mechanism may be similar. Suppose a car owner considers scrapping a car which is at the present time not eligible for the higher premium. (I.e. it has passed a vehicle inspection, and is thus legal to drive, but has not passed inspection within the stipulated time.) If there is a positive probability that the car will pass the next inspection, sufficiently large to justify the cost of keeping the car for another short period of time, then this consideration may delay scrapping the car. Again, there would be no offsetting incentive for any car owner to bring forward the scrapping of their car. Thus, the conditions attached to the higher scrappage premium may actually serve to increase the average life length of automobiles, contrary to the objective of the policy. It may appear odd that the number of scrapped cars still increase when the extra premium is increased. However, that may be the result of cars that would otherwise have been dumped somewhere instead of being properly taken care of. An alternative explanation for this apparent departure from the theoretical predictions is presented in the next paragraph.

In the regressions with the size of the car stock as the dependent variable, none of the coefficients, separately or in linear combinations, on the base premium variables are significantly different from zero at the 10 percent level of significance. A lowering of the extra premium seems only to have a temporary effect on the car stock, while an increase causes a reduction of the size of the car stock. Again, this does not seem to be in congruence with the predictions from the theoretical model. To see how this may be reconciled with theory, consider a situation where the optimal size of the car stock has fallen, perhaps due to an increase in the tax on car sales. As we saw above, we would not expect the actual size of the car parc to reach its optimal level immediately, but rather with a lag, the length of which will depend on the age composition of the car parc and the distribution in the population of the parameters α_j. But if the extra scrappage premium is raised during the adjustment period, the adjustment will happen faster, thus possibly accounting for the negative effect on the size of the car stock.

4 Policy implications

The effects of policies designed to reduce the negative environmental effects from automobile use may have undesirable side-effects. One reason for this is that an automobile give rise to negative effects during all parts of its life-cycle. Thus, measures that mitigate negative effects during one part of the life-cycle may increase pollution during some other period in the car's "life". Thus, we cannot determine whether a policy reduces environmental harm without considering the effects during the entire life-cycle. In this section, we will apply the framework presented in the paper to analyze two categories of policies, first, various accelerated vehicle retirement programs, and secondly, the diverse policies designed to implement the ELV directive.

The stated objective of most accelerated vehicle retirement programs, and also of the Swedish permanent scrappage premium, is to reduce vehicle emissions. Thus, we would like to translate the findings in the previous sections of this paper into net changes in such emissions. This is no simple task. However, we may draw some conclusions, at least with regard to which factors need to be taken into account. It turns out that both in the case of a temporary scrappage premium and in the case of a permanent premium, the effects on emissions will be ambiguous. In the last paragraphs of this section, we will consider which factors would need to enter a social cost and benefit analysis of an accelerated scrappage program, and discuss what lessons this would provide for the implementation of the ELV-directive.

Let us first consider a permanent scrappage premium. Theoretically, a higher scrappage premium will reduce the optimal life length of automobiles, and this will tend to reduce emissions. However, the size of the car parc will be increased, and this will tend to increase emissions. It is not a foregone conclusion which effect will dominate. Rather, whether the net effect will be positive or negative will depend on how the emission characteristics vary over the life of the automobile, and on the pace of technological progress.[8] Thus, if technological development is rapid, or if emission properties deteriorate rapidly towards the end of a car's life, then it may be justifiable to have policies designed to reduce the life length of automobiles. Instead of using a scrappage premium, however, we may adjust the ratio between the registration tax and the road tax to influence the life length of automobiles. Given

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[8]Naturally, it will also depend on the functions determining the optimal life length and the size of the car park.

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the total burden of taxation on cars, if a larger share of the tax revenues is obtained through a registration tax, the car owners will wait longer until they buy a new car. Another policy alternative may be to differentiate the road tax according to the age of the car. Naturally, other measures than taxes and subsidies may also be used to purge the car parc of highly polluting old automobiles. Such measures might include compulsory vehicle inspection, or more stringent technical requirements for automobiles.

Our empirical findings also argue against the use of a scrappage premium to try to influence the life-length of automobiles. It appears that the main effect of changes to the scrappage premium are only temporary, at least when the premium is comparatively small, as it is in the Swedish case.

Obviously, the "deposit-refund motive", i.e. the use of a scrappage premium to give a disincentive to uncontrolled, and illegal, scrappage of cars in forests and lakes, etc., is a separate issue. This issue is thoroughly analyzed by Bohm[7]. His findings indicate that on this measure, the Swedish scrappage premium system has been successful, at least in the first years of operation. Later on, when the real value of the premium was allowed to fall, due to inflation, the problem with abandoned cars reappeared, which further vindicates that the scrappage premium system worked.

Let us now discuss an "accelerated vehicle retirement program", such as the programs discussed in the introduction, under which a temporary scrappage premium is paid, and assume for the moment that it is introduced completely unexpectedly. Thus, we need not consider delayed scrapped cars. Our findings suggest that the oldest cars in the car park would then be scrapped as soon as, or at least shortly after, the temporary scrappage premium is introduced. These cars would then instantly, or almost instantly, be replaced by new cars. The reduction in emissions will thus be the difference between the emissions from the scrapped cars and from the new cars. Note, however, that if the emission properties of the automobiles deteriorate with the age of the cars, but are constant over time for cars of the same age, then total emissions over a car's life span will be the same. Thus, the size of the benefits would depend on how future emissions are discounted. If, on the other hand, emission properties of automobiles are improved over time, also given the car's age, then the emissions reduction will be permanent. However, after the scrappage premium has been abolished, and until the oldest cars that were not scrapped under the accelerated scrappage program reach their optimal life length, and are scrapped, no new cars will be sold, and no old cars scrapped. (Remember that the optimal life length of automobiles

as well as the size of the car stock are unaffected by a temporary scrappage premium.) This will tend to counteract the initial reduction in emissions, as automobile emissions will increase, or at least not decrease during this period. Had the temporary scrappage premium not been introduced, on the other hand, automobile emissions would have been reduced during this period due to technological improvements in new cars. The net effect on emissions seen over a longer period of time will thus be uncertain, and will depend not only on the pace of technological development, but also on whether the pace of technological development is relatively constant, or if it takes place by leaps. If technology develops by leaps, then the gain from getting rid of old polluting cars, after such a leap has taken place, may be large. If no major changes in technology take place in the period shortly after the accelerated scrappage program is abolished, then the counteracting increase in pollution may be small. The introduction of catalytic converters may be an example of such a "leap" in technology. Naturally, the same reasoning can be applied to technological advances that improve the safety of automobiles.

As we have discussed above, it is usually not realistic to think that a scrappage premium can be introduced unexpectedly. Suppose instead, and more realistically, that it is anticipated some time beforehand. We then need to consider car owners who delay scrapping their cars. If these cars are just kept in a parking lot, and not used, they will have no effect on emissions. If, however, they are used, perhaps because the automobile owner waits to buy a new car until the old one is scrapped, or as a second car, then this will have an off-setting effect on any emissions reduction. The number of delayed scrapped cars may perhaps be reduced by introducing more stringent requirements for an automobile to be eligible to receive the premium. However, that may induce car owners to take costly action to make the car eligible, e.g. by repairing it, thus increasing the social cost of delayed scrapped cars. From the inequality in (22) we know, however, that the number of delayed scrapped cars will decrease if the road tax is increased. Thus, if the road tax is increased when the scrappage premium becomes known, or some time before it is implemented, then this problem may be mitigated.

Making a social cost and benefit analysis of an accelerated vehicle retirement program or of a permanent scrappage premium must obviously involve an assessment of the net effect on emissions. Such an assessment would require assumptions about how technological development will affect specific emissions, as well as of how the age composition of the vehicle stock would

evolve with and without a scrappage premium. When a scrappage premium is introduced, we need to take account of delayed scrapped cars. Also, the cost incurred by a car owner (excluding taxes) of keeping the car until it is scrapped must be included in a cost and benefit analysis. In addition, the payment of a scrappage premium to car owners who would anyway have scrapped their cars will constitute a redistribution of resources, which may be unwarranted. If the accelerated scrappage program is publicly funded, and if the social cost of public funds is larger than unity, this redistribution will also give rise to a net social cost.

In addition, it must once more be pointed out that the additional environmental costs that arise due to the increased number of scrapped cars, and increased automobile production, must be included in the analysis. It is not certain that even a "successful" accelerated vehicle retirement program will improve the environment.

Based on theoretical consideration, the ELV Directive could cause an increase in the life-length of automobiles, at least under some of the policy options possible to implement so called "free" take-back of automobiles. As pointed out to in the introduction, the point of the Directive is to increase recycling of used cars beyond what is privately profitable. This cost is imposed on the producers and importers of cars, and will be shifted over to the consumers. It is naïve to a degree to think believe that the Directive's stipulation that "producers meet all, or a significant part of, the cost of implementing these measures" will have any effect on where the eventual cost of the policy falls. A plausible scenario is that prices of new cars will rise to cover the extra cost imposed by the Directive. Possibly, auto makers will have to offer some kind of incentive to owners of ELV:s to make sure that they will dispose of their cars properly, and not just leave them by the side of the road, or dump them in a lake. Thus, it is not unreasonable to think that something similar to the Swedish scrappage premium system will result. We have seen that this would, theoretically lead to an increase in the optimal life-length of automobiles. A "Danish system", however, where the extra cost is instead paid as an annual levy, will not have this effect. Rather, the Danish system may reduce the life length of automobiles, since the premium paid for scrapped cars is, at least at the present time, larger than the cost of scrapping the car. At the same time, we would expect any system that increases the cost of buying and owning a car to reduce the size of the car parc. The empirical analysis, however, indicates that the effects will not be that large, if at all noticeable, provided of course, that the ELV Directive

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does not increase costs drastically.

5 Concluding remarks

As have already been emphasized, this paper abstract from some complications in specifying the econometric model. The theoretical model also ignores some complications. Two important simplifications is that the supply of cars is not modelled, and that the market for scrapped cars is not included in the analysis at all. Let us first consider the supply of automobiles. The model in this paper predicts that a temporary scrappage premium would lead to a large temporary increase in the demand for new cars, followed by a sharp reduction in demand, before normal conditions return. Such swings in demand may affect prices, if demand is not perfectly elastic, and also industry profits, if some form of imperfect competition prevails. Whether profits will increase or decrease depends on market conditions. However, the fact that the automobile industry in several countries has lobbied in favor of introducing "accelerated vehicle scrappage programs" may indicate that the industry's representatives, at least, expect the effect to be positive.[9] We have also implicitly assumed that all taxes are fully shifted over to consumers. In practice, the price increase may be both larger and smaller than the tax change, depending on the market structure.

Interaction with the market for scrapped cars may also affect our results. Many parts of a discarded automobile have a market value. However, a sharp increase in the number of automobiles scrapped is likely to affect the price of used parts and of scrap metal. This is in fact one reason why the initially successful Swedish deposit-refund system failed to achieve its objective after a few years of operation. The price of scrap metal fell from SEK 130 per ton in 1975 to SEK -20 per ton in 1978, i.e. the scrappage firms had to pay to get rid of scrap metal.[7] Thus, effects on this market are likely to have important consequences for the success of a scrappage program. An exhaustive investigation into the effects of an accelerated vehicle retirement program would thus need to consider the supply of automobiles and the demand for scrapped cars. This also has implications for the implementation

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[9] It is easy to show that if the price is unchanged, and the profit margin is not affected, then industry profits will increase in the model used in this paper. Since the automobile stock will be unchanged, we will in effect move some car sales closer in time by introducing a temporary scrappage premium, thus increasing the net present value of profits.

of the ELV Directive. It is not obvious how the car dismantling and recycling industry will respond to the legislative changes brought by the Directive.

The treatment also ignores that cars sold today and cars sold ten years ago are quite different from each other. To take two instances, the average engine power of cars sold in Sweden in 2001 was 25 percent larger than in 1991. During the same period, the market share of four by four vehicles had increased from 1.9 percent of sold cars to 7.3 percent.[4] Obviously, technical progress is one driving force behind changes to the car parc. It should, however, be straight-forward to incorporate these complications within the framework presented in the theoretical section of this paper.

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Table 1 - The number of scrapped cars

Dependent Variable: Scrapped cars (1st diff)
Sample(adjusted): 1989:04 2001:12
Included observations: 153 after adjusting endpoints

Variable	Coefficient	Std. Error	
Constant	-254.7	136.4	*
GDP (2nd diff)	-0.01890	0.01542	
Price index, car (2nd diff)	3248	3434	
Price index, car ownership (1st diff)	4127	9141	
Real interest rate (1st diff)	-16767	22670	
Base scrappage premium (1st diff)	215.2	56.02	***
Extra scrappage premium (1st diff)	39.97	0.7908	***
Base scrappage premium (abs. value, 1st diff)	381.6	60.62	***
Extra scrappage premium (abs. value, 1st diff)	22.60	1.105	***
Base scrappage premium (lagged, 1st diff)	-57.47	47.91	
Extra scrappage premium (lagged, 1st diff)	-17.61	1.103	***
Base scrappage premium (lagged, abs. value, 1st dif	-233.0	45.30	***
Extra scrappage premium (lagged, abs. value, 1st dif	-7.659	0.9308	***
AR(1)	-1.154	0.005693	***
AR(2)	-0.9963	0.004797	***
MA(1)	1.143	0.005924	
MA(2)	0.9796	0.01480	
R-squared	0.9513		
Adjusted R-squared	0.9456		

Note: One, two and three asterisks denotes that the linear combination of parameters is significantly different from zero at, respectively, the 10-, 5- and 1-percent level.

Table 2 - Sold cars

Dependent Variable: Sold cars (1st diff.)
Sample: 1989:01 2001:12
Included observations: 156

Variable	Coefficient	Std. Error	
Constant	108.0	196.2	
GDP (2nd diff)	0.02668	0.04224	
Price index, car (2nd diff)	-2938	4649	
Price index, car ownership (1st diff)	-4196	8542	
Real interest rate (1st diff)	11977	20051	
Base scrappage premium (1st diff)	-73.79	65.87	
Extra scrappage premium (1st diff)	-2.288	1.314	*
Base scrappage premium (abs. value, 1st diff)	61.57	65.63	
Extra scrappage premium (abs. value, 1st diff)	3.987	1.166	***
Base scrappage premium (lagged, 1st diff)	178.6	58.68	***
Extra scrappage premium (lagged, 1st diff)	-0.1953	1.958	
Base scrappage premium (lagged, abs. value, 1st dif	-148.1	58.06	**
Extra scrappage premium (lagged, abs. value, 1st dif	-8.301	1.565	***
AR(12)	0.4864	0.07741	***
MA(1)	-0.5033	0.1213	***
MA(2)	-0.1576	0.08437	
MA(3)	0.1488	0.1104	
R-squared	0.4258		
Adjusted R-squared	0.3597		

Note: One, two and three asterisks denotes that the linear combination of
parameters is significantly different from zero at, respectively, the 10-, 5- and 1-
percent level.

Table 3 - Size of the car parc

Dependent Variable: Cars in use (2nd diff.)
Sample: 1989:01 2001:12
Included observations: 156

Variable	Coefficient	Std. Error	
Constant	182.6	192.1	
GDP (2nd diff)	0.1381	0.07956	*
Price index, car (2nd diff)	-6117	10012	
Price index, car ownership (1st diff)	-19080	10837	*
Real interest rate (1st diff)	23434	25998	
Base scrappage premium (1st diff)	-182.5	195.4	
Extra scrappage premium (1st diff)	-15.42	6.008	**
Base scrappage premium (abs. value, 1st diff)	186.7	191.0	
Extra scrappage premium (abs. value, 1st diff)	-2.842	6.076	
Base scrappage premium (lagged, 1st diff)	283.1	178.7	
Extra scrappage premium (lagged, 1st diff)	3.626	6.242	
Base scrappage premium (lagged, abs. value, 1st dif	-277.3	185.3	
Extra scrappage premium (lagged, abs. value, 1st dif	-6.282	6.480	
AR(12)	0.6353	0.09001	***
MA(1)	-0.8632	0.06012	***
R-squared	0.4983		
Adjusted R-squared	0.4485		

Note: One, two and three asterisks denotes that the linear combination of parameters is significantly different from zero at, respectively, the 10-, 5- and 1-percent level.

Table 4 - Linear combinations of parameters

	Scrappage		Sales		Car stock	
Increase in the base scrappage premium	596.8	***	-12.21		4.188	
Increase in the extra scrappage premium	62.57	***	1.700		-18.26	*
Lagged increase in the base scrappage premium	-290.5	***	30.54	***	5.841	
Lagged increase in the extra scrappage premium	-25.26	***	-8.496	***	-2.656	
Reduction of the base scrappage premium	-166.4		-135.4		-369.2	
Reduction of the extra scrappage premium	17.37	***	-6.275	***	-12.58	**
Lagged reduction of the base scrappage premium	175.5	*	326.8	***	560.4	
Lagged reduction of the extra scrappage premium	-9.947	***	8.105	***	9.908	
Total effect, increase in the base premium	306.3	***	18.33		10.03	
Total effect, increase in the extra premium	37.30	***	-6.796	*	-20.92	***
Total effect, reduction of the base premium	9.106		191.4		191.2	
Total effect, reduction of the extra premium	7.424	***	1.830		-2.669	

Note: One, two and three asterisks denotes that the linear combination of parameters is significantly different from zero at, respectively, the 10-, 5- and 1-percent level.