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# A quantitative model of accelerated vehicle-retirement induced by subsidy

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ABSTRACT

A number of accelerated vehicle-retirement programs have been implemented by private companies and public agents to reduce pollution and promote environment friendly technology. Our paper examines subsidy programs for the acquisition of a new low-pollution vehicle, provided that an old technology unit is retired. A model is developed to determine the appropriate subsidy level that induces the replacement of a specified number of existing old technology units within a given time period. Alternatively, given the subsidy level, the model allows the determination of the required time period to achieve a desired replacement target. In this way, the proposed method could be used to assess the effectiveness of a subsidy-based policy of accelerated vehicle-retirement in reaching a targeted number of scraped vehicles within a specified time framework.



## 1. Introduction

Societies and governments alike have demonstrated concern for improved environmental conditions (Remmers et al., 1990; Cooper, 1997). A number of measures have been taken towards this end by both private companies and public agents, with dubious results. In principle, economic efficiency requires a tax upon the product whose consumption generates a cost which is not included in its price. By the same token, subsidies are justified if total benefits from the consumption of a product exceed its market price. The issue of whether taxes on the release of pollution and subsidies on pollution abatement policies may achieve an identical solution as personal transfer payments has generated academic interest (Palmquist, 1990; Santos et al., 2010). The direction of the impact, however, remains unquestionable.

Regarding air pollution from vehicle emissions, voluntary accelerated vehicle retirement programs have been applied after 1990. Unocal Oil company initiated the first scrapping program offering owners of pre-1971 vehicles $700 to scrap their vehicle (Hahn, 1995). Since then, more than a dozen vehicle-buy-back programs, also known in the US as cash-for-clunkers, have been implemented in the US to reduce emissions (Dill, 2004). The Car Allowance Rebate System (CARS), implemented by the US Transportation Department in 2009, provided a subsidy of up to $4,500 for the replacement of an old car by a new more environmentally friendly vehicle. Eligible vehicles should have been manufactured not less than 25 years before the date they were traded in. The program achieved the replacement of nearly 680,000 vehicles with fuel efficient vehicles at a cost $2.85 billion (US Department of Transportation, 2009).

Vehicle scrappage programs have been adopted in many European countries during the last two decades (European Conference of Ministers of Transport, 1999). For example, between January 1, 1991 and March 31, 1993, the Greek government offered a significant tax reduction for the acquisition of new cars that use unleaded gas. The effectiveness of this scrappage/replacement policy has been studied by Baltas and Xepapadeas (1999). More recently, a large number of European countries implemented voluntary vehicle retirement schemes. In 2007, France ran a vehicle scrappage program, which retired cars with age exceeding fifteen years under the condition that low emission vehicles would be purchased. In December 2008, the program was extended to include the scrappage of more than ten years old vehicles (French Ministry for the Environment, Energy, Sustainable Development and the Sea, 2008). The voluntary accelerated vehicle retirement scheme, implemented in the UK from 2009 and 2010, retired vehicles older than ten years (UK Department of Business, Innovation and Skills, 2010 ). In many cases, the duration of a vehicle retirement program is limited by the available funds and its implementation is terminated once the budget is depleted. For example, during 2009, in Germany a scheme, which scrapped cars older than nine years for the purchase of new cars conforming to strict (Euro 4) emission standards, ran until the allocated amount of five billion Euros was depleted (German Federal Ministry of Economics and Technology, 2009 and 2011). Similar voluntary vehicle retirement programs have been recently adopted in Italy, Spain, Austria, Cyprus, Luxemburg, Portugal, Romania, Slovakia, and the Netherlands (Santos et al., 2010).

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In April 2009, Japan implemented a scrappage program, which provided a subsidy of ¥250,000, when a vehicle 13 years old or older was retired and a new car, which met low fuel efficiency standards, was purchased (Nun, 2009).

Limitations in the effectiveness of accelerated vehicle retirement programs in reducing emissions are investigated by Dill (2004) on the basis of large-scale programs in California. DRI/McGraw-Hill (1991) confirms that fuel consumption falls when old vehicles, through a retirement program, are replaced by new ones. Skepticism about the benefits and the eventual impact of scrappage schemes is expressed by Sandström (2003). Santos et al. (2010) provide a review of the ambiguity for the effectiveness of subsidy based vehicle retirement policies. The purpose of environmental and safety benefits of scrappage schemes, which require the purchase of a new unit, is often combined with or may even be driven by the objective to boost car sales in a period of economic recession to the automobile industry. This dual aim may be explicitly stated in the program objectives, as, for example, in the scrappage schemes in Germany (German Federal Ministry of Economics and Technology, 2009) or in UK (UK Department of Business, Innovation and Skills, 2010). It is interesting to note that the title of the law decree of the 2009 Italian retirement program was "Urgent measures to support industries in crisis" (Parlamento Italiano, 2009), without any reference to environmental considerations.

Tomohara and Xue (2009) examine alternative non-voluntary policies such as confiscation of old motorcycles with simultaneous owner compensation, or prohibition of the use of old motorcycles unless owners pay a fee. Fullerton and Gan (2005) compare the effect of a gas tax, a tax on distance traveled and an annual tax proportional to the emission rate of each vehicle, although the last one is not realistic. They conclude that for sport utility vehicles (SUVs) a tax on emissions appears to be superior, followed by the gas tax.

Our paper considers accelerated vehicle retirement programs under the condition of a purchase of a new vehicle replacing the old one. The purpose is to determine the required subsidy in order to achieve a specific replacement target of old polluting vehicles within a certain time framework. Alternatively, the model determines for a given subsidy, the replacement rate, which will occur, within a fixed time period. Finally, it is possible to derive the required time period within which the subsidy policy should be implemented in order to scrap a certain number of old vehicles. The structure of the paper is as follows. In Section 2, the theoretical background is examined and alternative approaches are reviewed. Section 3 introduces the model. An application in the case of linear demand for used and old vehicles with time dependent intercept is presented in Section 4, as an illustration of the model. In this framework, the required subsidy level, replacement rate and program duration are derived. Concluding remarks and qualifications are provided in Section 5.

## 2. Theoretical background

The model presented in this paper can be applied in a number of consumption activities with negative externalities. The application, which is considered, however, is in the context of the protection of clean air from car emissions. Vehicle exhaustion gases constitute, undoubtedly, one of the largest consumption externality.

In summary, our model assumes that new technology units, as for example, automobiles, are much more environmentally friendly than old ones, since age deteriorates motor vehicle emissions (Zachariadis et al., 2001; Zachariadis et al., 1995). Pollution coefficients for CO, $CO_2$, HC and $NO_x$ for different model years corroborate this claim (Lavee and Becker, 2009). Typically, new vehicles are manufactured in accordance to more stringent fuel consumption and gas emission standards. Higher safety is another feature of new automobiles.

To induce the purchase of new technology the government or a private entity offers a subsidy, whose level has to be determined, to buyers, who retire a conventional technology unit. The amount of subsidy is assumed to be independent of the type or age of the scrapped vehicle, as in most cash-for-clunker programs in the US (Dill, 2004) and the recent scrappage schemes in Europe and Japan. The accelerated vehicle retirement program that we examine requires the purchase of a new vehicle. The condition of a purchase of a new vehicle has been widely adopted in European scrappage programs and in the CARS program in the US. On the contrary, previous cash-for-clunker in Northern American programs did not pose this requirement (Dill, 2001), although it was estimated that approximately 85% of all vehicles retired each year were replaced by new vehicles (Kavalec and Setiawan, 1997).

It is interesting to observe that the instrument employed for pollution abatement is a subsidy and not a tax. Taxes and subsidies are usually considered as alternative tools, although some authors express their preference for taxes (Anthony Fisher, 1988). Frequently their choice is based on a potential disadvantage of a subsidy; it may have almost unlimited financial consequences on the government budget. A possible result of a subsidy may be the increase of the number of polluters and total pollution in the long run. In our model, the number of subsidy beneficiaries is limited and can not exceed the size of the population of existing old technology units. In brief, subsidy is not received unless an old technology car is withdrawn from circulation.

Although typically the impact of subsidies is on the supply curve, in our setting the subsidy is given to consumers, not producers, causing a shift up and to the right of the demand curve. The vertical distance between the two curves, the old and new *effective* demand is equal to the amount of the subsidy. Assuming a constant supply curve, the result is expected to be an increase in both quantity and price. The magnitude of the increase is determined by the relative elasticities of both curves.

It would be realistic to claim that the supply curve of vehicles for an open economy may be considered, in practice, perfectly elastic. Car industries produce at high scale and their models are sold in a large number of countries. The elastic supply curve would also be applicable for a number of advanced technology products. In a small or medium size economy, if during a period the demand increases, for some reason, the additional quantity can be supplied without raising costs and prices, since it represents a small fraction of the industry's potential. A similar argument is made for the supply of used cars by Lavee and Becker (2009) with reference to the economy of Israel. Past scrappage programs show that participation has often been, indeed, limited and the increase in demand relatively small. For example, the Bay Area Air Quality Management District (BAAQMD) program, which was one of the largest retirement programs, achieved to retire about 10,000 vehicles in a period of five years (Dill, 2004). In smaller scale programs such as the Delaware Vehicle Retirement Program only 125 pre-1980 vehicles were scrapped (Alberini et al., 1995). Similarly, under the Kern County (California) Auto Recycle-Program, 430 vehicles were retired, the Illinois Cash for Clunkers project resulted in 207 scrappages, and the South Coast Air Quality Management District scrapped 130 vehicles (Hahn, 1995). Even if participation in the scrappage program is substantial, as in the recent European and US vehicle retirement schemes, in the framework of a perfectly elastic supply, the price will not be affected and buyers will benefit the full amount of the subsidy. Our model considers a fixed per unit subsidy, which is not *ad valoren*. Therefore, the vertical distance of the two demand curves will be equal.

Alberini et al. (1995, 1996), using revealed and stated preference survey data of an accelerated retirement program of the state