“An economic and environmental measurement model on the Greek passenger vehicle market”

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Abstract

The aim of the paper is to investigate the economic and environmental effects of the economic incentives that promote the exchange or replacement of old passenger cars for newer, less-polluting models which would ultimately add to the alleviation of air pollution problems in the greater Athens area. The incidence of the scrappage/replacement policy is examined employing a model of optimal car replacement. Then, by analyzing the data during the period of policy application some quantitative indicators are derived. The results support the idea that the scrappage/replacement policy applied in Greece between 1 January 1991 and 31 March 1993 can be analyzed in terms of an optimal replacement model where subsidies on the purchase price of the clean car are introduced as a measure of environmental policy. The actual incidence of the policy, reduction in the age of the car fleet and reduction on the emissions, are in agreement with the results of the theoretical model.

Keywords: environment, pollution, policy, vehicle, taxation, market, replacement.

Introduction

The aim of the paper is to investigate the economic and environmental effects of the economic incentives that promote the exchange or replacement of old passenger cars for newer, less-polluting models which would ultimately add to the alleviation of air pollution problems in the greater Athens area. Emissions from petrol cars are considered the main contributors to photochemical pollution or "smog" since they are responsible for 98%, 73% and 77% of carbon monoxide (CO), hydrocarbons (HC) and nitrogen oxides (NC) emissions respectively in the Athens area.

In the first section, the Greek passenger car market as well as the development of retail prices in the respective Greek and EU markets are analyzed. The same section also deals with the passenger car taxation system and discusses the various categories of taxes in Greece as well as in the European Union. In the second section of the paper, the incidence of the scrappage/replacement policy is examined employing a model of optimal car replacement. Then, by analyzing the data during the period of policy application some quantitative indicators are derived. Finally, some concluding remarks are provided. The results support the idea that the scrappage/replacement policy applied in Greece between 1 January 1991 and 31 March 1993 can be analyzed in terms of an optimal replacement model where subsidies on the purchase price of the clean car are introduced as a measure of environmental policy. The actual incidence of the policy, reduction in the age of the car fleet and reduction on the emissions, are in agreement with the results of the theoretical model.

1. The Greek passenger car and light commercial vehicle market

Greece, together with Portugal, had one of the smallest vehicle to population ratios within the EU. In 1995 the ratio of inhabitants per passenger car in Greece is 5.16 which is more than two and one half times the "Euro" ratio (2.08), indicating the potential for substantial development of the market in future years.

The Greek inhabitant per vehicle ratio can be misleading if we exclude private commercial vehicles from its calculation, as they represent almost one quarter of the total stock of Greek private vehicles, this being the highest percentage in Europe. This consumer preference developed because of high taxes applied to passenger cars. This pushed manypotential PC buyers to purchase light commercial vehicles (LCV) as a cheaper alternative for private transport vehicle. In the European market, on the contrary, LCVs fulfill primarily business needs and constitute a small percentage (10-12%) of the total market. When LCVs are added into the calculation, the Greek inhabitant per vehicle ratio drops from 5.16 to 3.91. In the Athens area, the ratio is 2.74, which is even closer to the EU average[1]. This implies that most of the future potential for the growth of stock lies in the Greek provinces and not in the Athens metropolitan area which can be considered as reaching saturation as a vehicle replacement market.

Although, in absolute terms, the Greek car market has been one of the smallest in the EU (accounting for less than 1% of its market), it has recently been recording the highest rate of increase in the stock of PCs. For example, in 1961 the number of PCs and LCVs was 77,131 units, whereas in 1994 it reached 2,623,118; i.e. within a period of 34 years the number of units increased thirty-four-fold. The

[1] Association of Motor Vehicle Importers – Representatives (various issues).

corresponding figures for the Athens area are 6,500 units for 1956 and 1,273,769 units for 1994, an increase by nearly two hundred times, within a period of almost 40 years. However, this increasing trend has shown remarkable fluctuation. The basic reasons for this are the following:

- The very high prices of PCs, especially after the doubling of the tax on cars in 1979, kept the total number of sales at lower level than that corresponding to the country's size of population and standard of living. The government's decision to double taxes made the replacement of aged cars uneconomic. It resulted in a 60% drop in demand and a corresponding 38% decrease in fiscal revenues from cars in 1980 and subsequently. The effect of this policy was that since then the "life cycle" of circulating vehicles in Greece, already high before 1979, has increased. Another distortionary effect of this taxation was the importation of cars with large bodies in relation to the size of their engines. In most cases, these cars were characterized by a below normal body size/horse power ratio. In the EU member states, passenger cars belong to a specific category (segment), on the basis of the cars' characteristics and its size. With the exception of Greece, in the EU, engine capacity has nothing to do with the segment that the car belongs to and the tax coefficient applied to it. However, heavy and relatively underpowered cars had many negative consequences, such as higher emissions of exhaust gases, higher fuel consumption, shorter life cycles, and finally, less safety. At the end of 1994, 44.7% of passenger cars circulating in Greece had engines up to 1200 cc, while only 1.3% were over 2000 cc. The tendency, however, is in favor of 1.3L/1.4L engine cars over the last few years. In the LCVs, 62.4% of the circulating units belong to the pick-up band and only 33% to the van band. The remaining 4.6% are four-wheel drive, on/off road vehicles registered as LCVs.
- The introduction of the "inner ring", i.e. a restriction on passenger car circulation in the center of Athens, which is based on odd and even number plates. On even numbered calendar days, excluding weekends, circulation of cars with even number plates is allowed, while on odd days odd number plates may circulate. This system of circulation restrictions has been in force since 1980. In the meantime, given the inefficiencies of the public transport system, many Athenians were motivated to purchase a new passenger car and to keep the old car as well in order to have both an odd and an even license plate.

Thus, government policy on passenger cars in the 1980's had a direct impact on the scrappage rate and the replacement of aged cars. It led to the doubling of circulating vehicles in the period of ten years. This considerable increase in the number of cars is mainly due to the limited withdrawal of old cars as increasing numbers of new cars were entering circulation. Government policy has led to a big increase in the average age of circulating vehicles which rose from 7.4 in 1980 to almost 11 years by the end of 1990 (Figure 1). No other EU country has an average age of circulating vehicles exceeding 8 years or a life cycle for these vehicles exceeding 25 years. At the end of 1990, Greece had about 280,000 petrol-engine vehicles in circulation that were between 15 and 20 years old and a further 175,000 that were over 20 years old. These two age groups together represent 21% of the total fleet of petrol-engine vehicles. These developments have considerably increased atmospheric pollution in urban areas, particularly in Athens. They have also increased fuel consumption and the demand for parts and have additionally caused some road safety problems.

From 1989 onwards, the government's taxation policy aimed at a gradual reduction of tax rates for "clean" passenger cars equipped with catalytic converters. This was the first antipollution incentive and also the first step towards harmonization of the Greek taxation system with the ones applied in the rest of the EU countries. In 1990, the number of "clean" cars rose from 86,000 to 115,000, a 34% increase in one year.

In November 1990, the Ministry of the Environment in cooperation with the Ministry of Finance announced additional financial incentives for the replacement of old petrol cars with new "clean" ones. These incentives went into effect in January 1991 and resulted in total sales reaching 167,000 units in 1991. In 1992, the second year in which the measure was in effect, sales continued their upward trend reaching 200,000 units.

It is important to note that the scrappage/replacement financial incentives introduced between 1991-92 substantially reduced the rate at which the fleet of circulating cars increased. During these two years, 332,000 old polluting cars, 150,000 of which were in the Athens area, were replaced. Moreover, the rate at which the fleet of private vehicles was growing dropped from 7.0% in 1990 to 2.8% in 1991 and to just 2.0% in 1992. With the termination of the incentives, this rate of growth rose again and reached 6.5% in 1993. If the same policy had been continued, in a few years time Athens could have run the risk of becoming the European city with the highest cars per inhabitant ratio. Of course, it should be noted at this point that a determining factor for slowing down the rate of growth of circulating units in the Athens

area has been the modernization of the public transport system and the operation of the Metro that is now under construction.

1.1. The taxation system of passenger cars in Greece. During the last two decades, there have been no marked changes in government policy toward PCs with the exception of the doubling of taxes in 1979. On the other hand, the beginning of the 1990's signalled a major shift in the fiscal treatment of PCs. The reasons behind the new attitude were the recognition of the acute air pollution problems in the urban areas, especially in the greater Athens area, and the identification of aged cars emissions as the main source of this pollution. Thus, in March 1990, the Greek government took the initiative to control pollution by introducing the first economic incentives in favor of "clean" cars.

Emissions from petrol cars are considered to be the main contributor to photochemical pollution or smog. According to recent studies[1], petrol cars alone are responsible for 99%, 73% and 77% of carbon monoxide (CO), hydrocarbon (HC) and nitrogen oxide (NO_x) emissions respectively in the Athens area. Overall, 80% of the exhaust emissions producing the photochemical pollution are attributed to PCs. Answering the need to reduce car-generated emissions, the first economic instrument toward clean cars was introduced in March 1990, as part of a five-year program aimed at decreasing HC. CO and NOχ emissions to their 1970 levels by 1996. The program included incentives for the replacement of aged petrol cars with new "clean" ones, the replacement of the entire fleet of public transport vehicles in the Athens area and the renewal of the taxi fleet.

In 1990, the first initiative under the program was announced in the form of lower taxes for the replacement of aged petrol vehicles with clean ones equipped with catalytic converters. This action was in line with the EU anti-pollution emission standards that became obligatory on January 1st 1993. A year later, another policy instrument was put into effect. This time, the State introduced incentives for the scrappage and replacement of old petrol vehicles in the form of even lower taxes and a scrapping refund that was received when an aged car was replaced with a new one equipped with a catalytic converter.

According to the Greek taxation system, private cars are subject to the following categories of taxes:

- acquisition taxes;
- registration taxes;
- circulation taxes;
- car inspection fee.

The acquisition tax is a one-off charge paid when a vehicle, new or used, is acquired. It consists of tax on the retail price of the car and a special traffic fee. The tax on the price of the car depends on the cars' engine capacity (cc), and its rate is related to a corresponding taxable Horse Power (HP), which is defined by the tax authorities. Registration fees are paid once a year and are banded according to car engine capacities. Circulation taxes are in the form of indirect charges and consist of a sale tax on fuel and a percentage charge on the vehicle's insurance premium. Lastly, the technical inspection fee is paid each time the vehicle passes technical inspection in order to obtain a smog control certificate.

Acquisition taxes are regarded as by far the most significant ones since they have considerable impact on the determination of PC purchase prices, which include the value of the vehicle, import tariffs, the special traffic fee and additional charges on the price, such as the Special Consumption Tax (SCT) and the Value Added Tax (VAT). Tax differentiation provided by the government for boosting sales of "clean" cars targeted the SCT rate which is directly linked to cars' engine capacity (cc). In March 1990, PCs equipped with catalytic converters were subject to the following SCT tax rates[2]:

Table 1. SCT tax rates

Band	Engine (cc)	SCT tax rate (March 1990)
A	Up to 600cc	35%
B	601cc-1400cc	50%
C	1401cc-1600cc	70%
D	1601cc-1800cc	90%
E	1801cc-2000cc	140%
FGH	1801cc-2000cc	220%

Then, in January 1991, incentives for the scrappage of old cars were introduced in the form of a discount on the SCT rate. However, these incentives were in force only until December 1992 when new rates were applied. The rates[3] valid as of January 1991, with the discount, and as of January 1993, without the discount, were set as follows:

Table 2. SCT tax rates

Band	Engine (cc)	January 1991 (with scrapping)	January 1993 (without scrapping)
A	Up to 600cc	14%	30%
B	60 lcc-1400cc	20%	38%
C	1401cc-1600cc	35%	43%
D	1601cc-1800cc	47%	48%
E	1801cc-2000cc	70%	60%
FGH	Over 2000cc	220%	100%

The Greek tax system divides PCs and LCVs into groups (bands) according to vehicle engine capacity.

[1] Ministry of the Environment (1994), Bitros (1988; 1990).

[2] Ministry of the Environment (1990).

[3] ABC Automobile Business Consulting (1991).

Notice that this kind of banding does not apply in any other EU country.

1.2. Effects of the Greek taxation system. To realize the degree to which the various surcharges of the Greek taxation system burden the retail price of PCs, a simplified example is provided from a recent study[1]. Let's calculate the ratios between the retail price of a 1400 cc PC and the sum of its CIF value, duties, fees and the mark-up of the local representative under three different scenarios: (a) old technology car, (b) car equipped with catalytic converter, and (c) car equipped with catalytic converter and eligible for a scrapping refund.

Table 3. Ratios between the retail price of a PC and the sum of its CIF value, duties, fees and the mark-up of the local representative

Old technology	2.676
Equipped with catalytic converter	1.653
Equipped with catalytic converter and eligible for a refund	1.394

The differences of these ratios demonstrate the degree to which the fiscal incentives for new technology PCs have affected their acquisition price. Thus, PC retail prices in the Greek car market have dropped considerably due to tax differentiation; however, they still remain 50% to 60% higher than the corresponding one without the surcharge price of the car.

In 1990 the lower retail prices induced a 35% increase in car sales, the highest annual rise in Europe. Moreover, there were dramatic changes in the demand for PCs in terms of their taxable HP. Demand for all PC bands up to 8 taxable HP (1072cc - 1214cc) dropped, given that until then they were subject to an 88% tax rate whereas the next higher band had a 138% tax rate. The corresponding new rates are 60% and 50% respectively. Thus, the new rates significantly narrowed these inequalities. On the other hand, no significant changes occurred in the demand for PCs in terms of size bands[2].

It should also be noted that the introduction of lower rates for PCs began to shift the demand away from LCVs. The year-on-year demand, for new and used LCVs increased during the four years prior to 1990, by 10%, 16%, 27% and 7% respectively. The sudden drop of the rate of increase to only 7% in 1990 is linked to the shift in demand from LCVs to PCs due to the considerable decrease in the retail prices of the latter. As a result, the 3:1 ratio between passenger cars and light commercial vehicles that existed in 1989, rose to 4:1 only a year later. Notice that the latter ratio is considered to be closer to the real needs of Greek motorists since in previous years the tax regime favored the cheaper LCVs as an alternative solution to the expensive PCs. In fact, most of the LCVs taken off the road under the scrapping refund scheme were replaced by "clean" PCs instead of new LCVs.

1.3. European Union and taxation policies. Taxation systems applied to private passenger cars in the member countries of the EU are not characterized by homogeneity. There are similarities as well as dissimilarities among the various taxes and charges imposed. The main discrepancy is attributed to the different taxing scale upon which levies, duties or tax coefficients are calculated.

1.3.1. Acquisition taxes. Acquisition taxes enforced by the various member states include VAT on new or used cars, the classification tax, the registration fee, license plates dues, stamp duty, car tax, special duty, transfer tax and the SCT. Not all of these taxes are imposed by every country. However, the major difference among taxation systems is not the number of taxes imposed but the different financial terms on which VAT evaluation is based. Notice that among the various acquisition taxes, VAT represents the largest surcharge.

In Belgium, Spain and Luxembourg, VAT is calculated on the value of the invoice at the time the car is sold. In France and Germany, VAT is rated on the value of the invoice without any surcharge sale price of the car. In Denmark and Germany, VAT is computed upon the tariff value. In Great Britain and Portugal, VAT is calculated on the value of the invoice in which the car tax is also incorporated. In Italy, VAT is based on the value of the invoice without tax sale price, whereas in Holland it is based on the sale price in which the SCT is also included. Lastly, in Greece VAT is calculated on the total retail price of the car, including from 1993 the Registration Tax.

Another point of differentiation is the process of calculating the special traffic fees. These fees include the registration fee and the rate of issuing license plates. In Germany. Spain, Italy, Luxembourg, Holland and Portugal, but not in the otner countries of the EU. these fees are directly linked to cars' engine capacity. In Great Britain this kind of fee does not exist.

1.3.2. Ownership taxes. In every member country, property taxes of private cars are paid each year but again 110 anonymous ways of appraisal are applied. Determination of these taxes is based on the HP, the age of the car, the province of registration, the cars' engine capacity, the type of fuel used or the weight

[1] Association of Motor Vehicle Importers – Representatives (various issues).
[2] According to related studies, band "C", which in 1990 represented 44% of total demand had an increasing trend, band "A" which represented 26.3% of total demand had a decreasing trend and band "D" showed an increasing trend during 1991 reaching 19.9% of total demand. The increase in the market share of band "D" is attributed to the diversification in tax charges since the beginning of 1991 (Association of Motor Importers – Representatives, 1991).

of the car. Moreover, the categories of the taxes implemented by every government vary. For instance, there are road fees, circulating fees, ownership charges as well as car levies.

1.3.3. Circulation taxes. These charges can be classified in the following two categories:

- direct charges (various fiscal fees, radio charges and charges on the use of highways); and
- indirect charges (on the price of fuel).

The first category is paid once a year but again not all of these charges are implemented by every country. However, the indirect charge imposed on unleaded benzene is lower that the other fuels in every state. The reason is that exhausts from unleaded benzene are considered as less polluting. Greek charges on fuel are among the lowest in the EU since in the rest of the member countries fuel is also subject to VAT. In Holland, the price of fuel, except unleaded benzene, contains a 1.46% and 6.49% tax on benzene and diesel respectively, which is spent on environmental protection. For the same reason, the Greek government imposes a 2.5% tax on the price of benzene which is credited to the Ministry of the Environment. Except Great Britain, Holland and Portugal, in all the other countries of the EU car insurance contracts are surcharged with taxes varying from 3% (Ireland) to 50% (Denmark) of the premium. In Greece, this surcharge is set at 20% of the premium. Radio charges and charges on the use of highways are imposed only in Italy.

2. A measurement model of car replacement and policy incidence

To analyze this policy we develop a model of optimal car replacement. Using this model we examine the impact of policy measures on the optimal car replacement time and on total emissions of pollutants. These policy measures can take the form of:

- reduced taxes on purchases of new "clean" cars. This instrument can be regarded as a subsidy of the initial cost of purchasing the car;
- administrative measures to reduce car usage (traffic restrictions);
- fuel taxes aimed at reducing car usage.

By comparing the choice of the optimal replacement time under market equilibrium, when individuals do not take into account the effects of their emissions on welfare, with the choice at the social optimum, when the environmental regulator (government) takes pollution damage into account, we determine the structure of the optimal subsidy for car replacement. The conceptual model for determining the optimal car replacement time is similar to the one used by Alberini et al. (1995). This model differs, however, from the one mentioned above in that we treat the policy instruments as parameters for the optimal replacement time selection in market equilibrium. Thus, in a second stage, we are able to model an environmental regulator as a Stackelberg leader who takes into account external environmental damage from car emissions and chooses the policy parameters to maximize a social welfare indicator.

Additionally, by using data on car scrappage and replacement and on emissions of pollutants during the period of policy application we derive some quantitative indicators of the policy incidence.

3. Empirical evidence of the replacement policy

The optimal replacement model mentioned above predicts that financial incentives in the form of tax reductions[1] on the purchase price of clean cars will accelerate car replacement, thus leading to subsequent reductions in emissions of pollutants and the average age of the car fleet[2]. This section examines the actual changes in emissions and fleet age brought about by the scrappage/replacement policy in Greece and explores whether these changes were in accordance with the predictions of the optimal replacement model.

Government policy on passenger cars in the 1980's led to very high car prices, especially after the doubling of the tax on cars in 1979's and had a direct impact on the scrappage rate and the replacement of aged cars: it led to the doubling of circulating vehicles within a period of ten years. This considerable increase in the number of cars is mainly due to the limited withdrawal of old cars along with the number of new cars entering circulation. Government policy has led to a big increase in the average age of circulating vehicles which increased from 7.4 in 1980 almost 11 years by the end of 1990 (Fig. 1)[3].

Recent studies[4] have shown that the main contributors to air pollution in the Athens area are private cars, industry and central heating. The contribution of cars to the emissions of major pollutants in the greater Athens area is:

[1] The analysis is kept at the partial equilibrium level. Thus, we do not examine possible complications arising from the reduction of tax revenues and the fact that public funds may be constrained by an opportunity cost that exceeds unity.

[2] Although we concentrate on the reduction of emissions, there are additional side benefits from car replacement, including fuel and spare part savings and traffic accident reduction.

[3] No other EU country has an average age of circulating vehicles exceeding 8 years and a life cycle for these vehicles exceeding 25 years. At the end of 1990, Greece had about 280,000 petrol-engine vehicles in circulation that were between 15 and 20 years old and a further 175,000 that were over 20 years old.

[4] National Report of Greece (1992).

- 73% of total emissions of hydrocarbons (HC);
- 77% of total emissions of nitrogen oxide (NO_x);
- 98% of total emissions of carbon monoxide (CO).

Estimates of emissions of the above pollutants obtained after the introduction of the scrappage-replacement policy indicate that the following average reductions in the annual emissions of the above pollutants have taken place[1]:

- HC: 8-10%, or approximately 6,500 tons a year;
- NO_x: 3-5%, or approximately 900 tons a year;
- CO: 15-17%, or approximately 90,000 a year.

There has also been a noticeable reduction in the average age of the passenger car fleet in the Athens area, as shown in Figure 1[2].

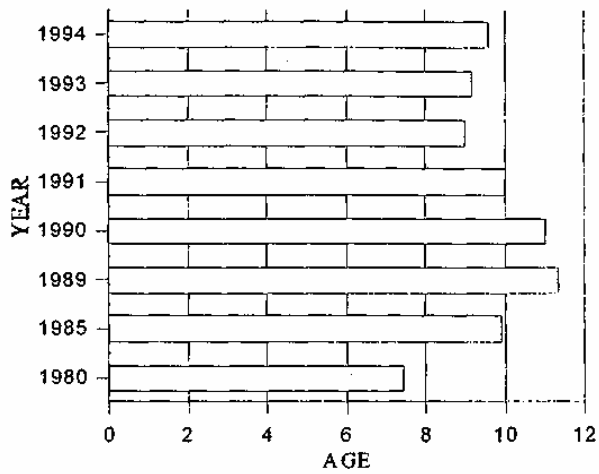

Fig. 2. Average age of passenger car fleet

The average age of the fleet reaches a minimum in the period of 1991-1993. This average age, however, begins to increase again following the abolition of financial incentives after 31 March 1993.

It is clear that the scrappage replacement policy operated as an economic instrument of environmental policy and its effects correspond fully with those predicted by the theoretical model. More insight into the incidence of the policy can be obtained by examining the evolution of the passenger car circulating stock (Figure 2) which shows that the rate of increase of the circulating stock of PCs in the Athens area slowed down during the period of 1990-1992. Figure 3 presents the percentage change in the stock and the proportional replacement rates for Greece. Clearly, there was a deceleration in the stock's rate of growth during the period in which this policy was in effect.

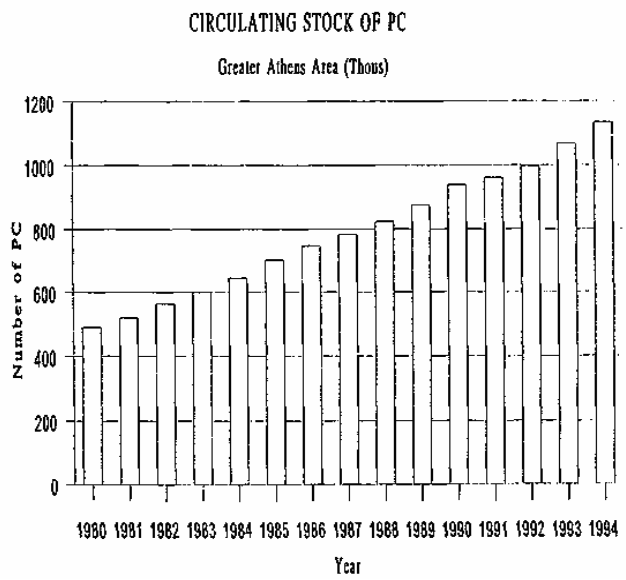

Fig. 2. Circulating stock of passenger cars

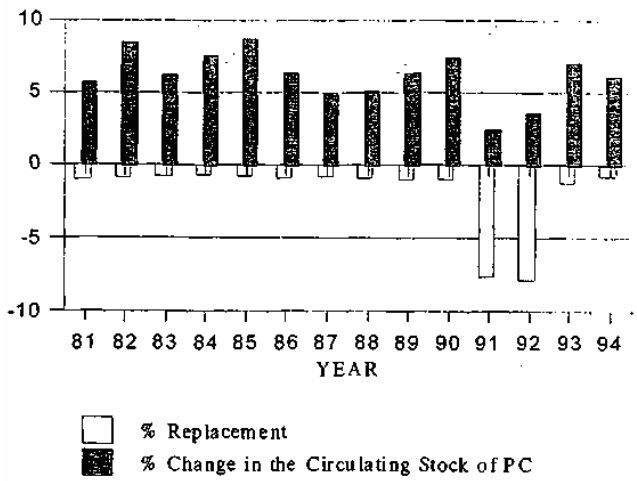

Fig. 3. Stock changes and replacement rates

Even more noticeable are the extremely high replacement rates[3] in 1991 and 1992 as a result of the policy. A study[4] carried out in the mid-90's estimate that if incentives were reintroduced the replacement rate (which dropped to 1% after the termination of the policy) would jump to 6% and the expected reduction of emissions by 1999 would be: 50% for CO, 36% for NO_x and 50% for HC.

The estimated emission reductions are, of course, a very strong indication of the effectiveness of the policy. Additional evidence supporting the idea that the policy was effective in terms of pollution reduction relates to the concentration of the pollutants (stock of pollution) which is the main source of environmental damage. Figure 4 presents average annual pollutant concentrations measured at

[1] Estimates were provided by the Ministry for the Environment (1994). An extensive monitoring system was established to make sure that "scrapped" cars were actually taken out of circulation.
[2] Association of Motor Vehicle Importers – Representatives (1995).

[3] The rate of replacement is defined as the percentage of passenger cars replaced each year in relation to the total passenger car fleet. Wherever there is only voluntary withdrawal of aged cars, without any incentive scheme for acceleration of replacement, this percentage ranges betwen 0.5 and 1%.
[4] A. Progiou (1995).

the Patission Street monitoring station in Athens. After 1990, there is an observable downward trend in pollutant concentrations. Although this downward trend cannot be entirely attributed to the policy, the fact that Palission is a "hot spot" of downtown Athens could provide some justification for crediting the policy with the reduction in concentrations. Additional insight can be gained by trying to relate the evolution of the concentrations with the policy by means of an empirical relationship. Two models have been estimated, one linear and the other logarithmic, of the form:

$$CO_t = \alpha+\beta REP_t+\gamma t,$$

where *CO* is annual average concentrations of CO, *REP* is the annual replacement rate and *t* is a time trend. The replacement rate is taken as the closest proxy of the policy of financial incentives since, as was shown in Figure 3, there was a sharp increase in annual rates as a result of the policy. The results from the linear and the logarithmic model are presented in Table 1.

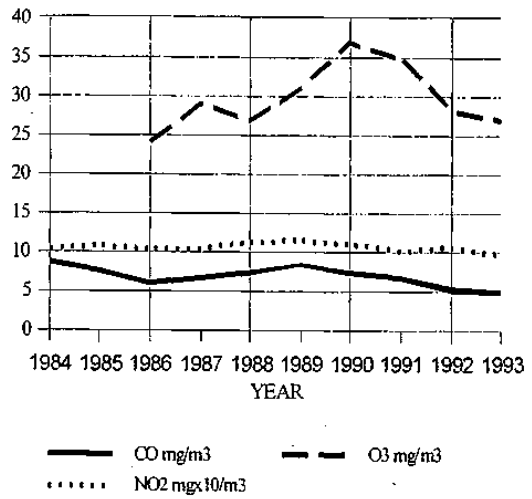

Fig. 4. Average annual concentration (measurements at Patission Street)

Table 1. CO concentration and car replacement relationships

Dependent variable	Constant	REP	t	LogREP	R^2	DW
CO	0.438 (12.318)	-0.1487 (-1.190)	-0.3301 (-2.764)		0.5226	1.345
LogCo	2.197 (21.52)		-0.0535 (-3.038)	-.0.0803 (-1.464)	0.5689	1.383

Note: t-ratios are in parentheses.

Although the number of 10 observations is small, the results indicate a negative relationship, albeit not a very strong one, between concentrations and replacement rate and confirm the negative trend in CO concentration. It could be argued that while the time trend embodies the effects of factors other than the scrappage/replacement policy, the replacement variable embodies the effects of the policy itself. Unfortunately, the relatively short length of time the policy was in effect makes it difficult to isolate its longer-term effects on the concentration of pollutants.

The above analysis suggests that the scrappage/replacement policy applied in Greece between 1 January 1991 and 31 March 1993 can be analyzed in terms of an optimal replacement model where subsidies on the purchase price of clean cars are introduced as a form of environmental policy. The actual effect of the policy in Greece, in terms of emission reductions and lowering of the age of the car fleet, are in agreement with the results of the theoretical model. This implies that qualitative predictions of the policy effects derived by theoretical models can be used to analyze in more depth the effects of environmental policy related to passenger cars.

The results are in accordance with results obtained by Hahn (1995), regarding scrappage policy programs in the USA, where it is shown that these programs can achieve cost effective reductions related to HC and NO_x emissions.

The analysis indicates therefore that reduced taxes for the purchase of new "clean" cars in Greece worked as an economic instrument of environmental policy. Moreover, its effects were in accordance with what would be expected from theoretical policy models. Regarding the effects from the discontinuation of the policy, initial data indicate that the average age of the car fleet in Greece has tended to increase again. This could have possible adverse effects on the emissions and the concentration of air pollutants, although as noted by Hahn (1995) scrappage could be regarded as a transitional strategy since once the relatively dirty cars have been removed, gains from scrappage diminish fast. Even, however, if scrappage policy is to be regarded as a short-lived instrument, its application in selected cases seems to provide an effective way to control vehicle emissions.

Concluding remarks

A model of optimal car replacement is used to examine the impact of alternative policy measures on optimal car replacement time and on total emissions of pollutants. These measures can take the form of: (i) reduced taxes on purchases of new "clean" cars, (ii) traffic restrictions, and (iii) fuel taxes aimed at reducing car usage.

It is shown that while a subsidy on the initial purchase price of the car brings forward the optimal replacement time, the impact of the two other measures on this time is ambiguous. This implies that whereas the subsidy on initial cost tends always to reduce emissions, the other two policy instruments have a first-round effect that tends to reduce

emissions and a second-round effect which could delay replacement time and thus increase emissions.

By analyzing data on car scrappage and replacement rates and on emissions of pollutants during the period in which this policy was in effect in Greece, some quantitative indicators of the policy's effectiveness are derived. The results support the idea that the scrappage/replacement policy applied in Greece between 1 January 1991 and 31 March 1993 can be analyzed in terms of an optimal replacement model where subsidies on the purchase price of clean cars are introduced as a form of environmental policy. The actual incidence of the policy in Greece, in terms of emission reductions and reduction in the age of the car fleet, are in agreement with the predictions of the theoretical model.

An empirical relationship is estimated between concentration of pollutants and car replacement rates. A negative relationship is suggested between the scrappage/replacement policy and the concentration of CO. Thus increasing the replacement rate reduces CO concentrations. Additional data sets are required however in order to establish the exact structure of the relationships between pollutant concentration and scrappage/replacement policy.

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