The environmental effects of tax differentiation by vehicle characteristics: results from Costa Rica

Jaime Echeverría, Nick Johnstone, Ronald Mejías and Ina Porras

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Environmental Economics Programme
IIED, 3 Endsleigh Street
London WC1H 0DD, UK
Tel +44 (0)20 7388 2117; Fax +44 (0)20 7388 2826
e-mail: Jacqueline.Saunders@iied.org

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IVM, Vrije Universiteit
De Boelelaan 1115
1081 HV Amsterdam
The Netherlands
Tel: +31 20 444 9555; Fax: +31 20 444 9553
e-mail:secr@ivm.vu.nl

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Abstract

Urban pollution, particularly from mobile sources, is a growing problem in Costa Rica, as elsewhere. Policymakers have tried to address this through traditional regulatory instruments, including the use of catalytic converters, compulsory vehicle inspection and maintenance programmes and random controls on roads. Yet other more general policy initiatives, such as reducing taxes, have contributed to greater car ownership and use, and hence pollution levels.

This study looks at differentiating car taxes on the basis of vehicle characteristics a means for improving air quality in Costa Rica. While the government already differentiates taxes by characteristic, this is not done explicitly for environmental reasons. Studies have demonstrated that a number of vehicle characteristics such as engine size, vehicle age and weight and other factors have a significant effect on emissions rates.

The results indicate that a tax which increases the relative price of used cars will have significant environmental impacts, while others means of differentiation (engine size and vehicle type) are much weaker. Moreover, since the present tax in Costa Rica is biased in favour of used cars, the case for 'neutralising' this bias on environmental grounds is likely to be stronger on efficiency grounds. However, as relatively poorer households have tended to buy smaller used cars, a change in the tax rate which increases their relative price is likely to be regressive. Yet applying taxes which favour the import of used cars is not the best way to achieve distributional objectives, particularly since the poorest are not likely to own a car of any sort.

Abrégé

Au Costa Rica comme ailleurs, la pollution urbaine, due en particulier à des sources mobiles, pose de plus en plus de problèmes. Les responsables politiques ont essayé de s'y attaquer à l'aide d'instruments régulateurs traditionnels : emploi de pots catalytiques, obligation de soumettre les véhicules à un examen technique et à un programme d'entretien, avec contrôles effectués au hasard sur les routes. Or ce sont des initiatives politiques d'ordre plus général, telles que la diminution de la fiscalité, qui ont contribué à la possession et à l'usage plus largement des automobiles et donc aux degrés de pollution enregistrés.

Cette étude se penche sur une différenciation de la fiscalité automobile sur la base des caractéristiques des véhicules, conçue comme moyen d'améliorer la qualité de l'air au Costa Rica. Si le gouvernement procède déjà à une telle différenciation, il ne le fait pas pour des raisons environnementales avouées. Des recherches ont démontré qu'un certain nombre de caractéristiques de véhicules (taille du moteur, âge et poids du véhicule, ainsi que d'autre facteurs) influent de manière significative sur les taux d'émissions.

Les résultats de l'étude montrent qu'une taxe accroissant le prix relatif des voitures d'occasion aura un impact sensible sur l'environnement, alors que d'autres méthodes de différenciation (taille du moteur et type de véhicule) s'avèrent beaucoup moins efficaces. Qui plus est, comme l'actuelle taxe automobile perçue au Costa Rica comporte un biais en faveur des voitures d'occasion, la justification d'une "neutralisation" de ce biais, énoncée au plan environnemental, risque fort de se trouver renforcée si on la situe au plan de l'efficience. Cependant, dans la mesure où les ménages relativement moins aisés ont eu tendance à acquérir des voitures d'occasion plus petites, une modification du taux de taxation, si elle augmente le prix relatif de ces véhicules, pourrait bien s'avérer régressive. Pourtant, appliquer des taxes favorables aux importations de voitures n'est pas la meilleure manière d'atteindre des objectifs de redistribution, surtout si les plus pauvres ne risquent guère de posséder de voiture, quelle qu'elle soit.

Resumen

Como en todas partes, la contaminación urbana proveniente de fuentes móviles es un problema creciente en Costa Rica. El diseño de políticas ha respondido mediante instrumentos regulatorios tradicionales como el uso de convertidores catalíticos, inspección vehicular obligatoria, programas de mantenimiento y controles aleatorios en las vías. Sin embargo, iniciativas generales de política tales como la reducción de impuestos, han contribuido a aumentar la adquisición y el uso de vehículos lo cual a su vez ha ayudado a elevar los niveles de contaminación.

Este estudio examina la diferenciación de impuestos según características vehiculares como un modo de mejorar la calidad del aire en Costa Rica. A pesar de que el gobierno reconoce una diferencia impositiva según características, esto no se ha hecho explícitamente por razones ambientales. Se ha demostrado mediante estudios que una serie de características vehiculares tales como el tamaño del motor, la edad y el peso del vehículo, además de otros factores, tienen un efecto significativo en las tasas de emisión.

Los resultados indican que un impuesto que eleve el precio relativo de vehículos usados tendrá un impacto ambiental significativo, mientras que otros medios de diferenciación (tamaño del motor y tipo de vehículo) serán menos efectivos. Además, dado que la carga impositiva en Costa Rica favorece actualmente a los vehículos usados, desde el punto de vista de la eficiencia, habrá justificación en intentar "neutralizar" esta situación para efectos ambientales. Sin embargo, dado que los hogares menos favorecidos tienden a comprar vehículos usados pequeños, un cambio en la tasa impositiva que aumente su precio relativo, será una medida regresiva. La aplicación de impuestos que favorezcan la importación de vehículos usados no es la mejor manera de mejorar la distribución de ingresos, ya que los más pobres suelen no poseer ninguna clase de vehículos.

Contents

Introduction

There is a growing recognition of the importance of incorporating environmental considerations in national development strategies. In the case of Costa Rica, air pollution has become a major concern, and mobile sources (motor vehicles) are significant contributors. The problem is particularly acute in urban areas. In San José, where 88% of both the vehicle fleet and the manufacturing sector are located, the maximum amount of suspended particles established by the WHO was already being exceeded by 1989 (MOPT 1990 and ECODES 1989). It has been estimated that 70% of the pollution in the city originates from mobile sources. According to the National Meteorological Institute of Costa Rica (NMI 1996) in 1990 mobile sources were responsible for 80.1% of total carbon monoxide emissions, 18.8% of methane (CH_4) 99.9% of non-methane volatile organic compounds (NMVOC), 58% of nitrous oxide (N_2O), and 87.1% of nitrogen oxides (Nox).

This report provides an overview of the potential environmental benefits of a particular type of environmental policy instrument to address the problem of air pollution from mobile sources in Costa Rica. More specifically, the case for the use of taxes based upon vehicle characteristics (eg, engine size, vehicle age, vehicle type) is examined. This instrument has been chosen because the Costa Rican government already differentiates taxes by characteristic, although the motivation for doing so is not explicitly environmental. Moreover, a well-chosen vehicle characteristics tax can be a good proxy for taxes based directly upon emission levels.

Following this introductory section, Section 2 discusses the public policy context in Costa Rica. Section 3 reviews the environmental significance of adjustments in the characteristics of the vehicle fleet. Section 4 reviews some empirical estimates of the effects of tax differentiation on the composition of the fleet and provides the results of some simulation exercises of the environmental effects of tax differentiation. And finally Section 5 discusses the policy implications.

Public Policy and Motor Vehicles in Costa Rica

Policymakers in Costa Rica have tried to address the problem of pollution arising from mobile sources through the use of traditional regulatory instruments. In particular, the *ecomarchamo* programme mandates the introduction of catalytic converters, and stringent regulations have made them mandatory for all gasoline-powered vehicles introduced into the country since 1995. A compulsory vehicle inspection and maintenance programme was introduced in 1995 and is managed by the private sector in a decentralised manner. In addition, since 1993 there have been random controls on roads, measuring carbon monoxide and particulate matter with mobile equipment.

However, in some ways other more general aspects of public policy have been more important determinants of pollution levels from vehicles. In particular, there have been two distinct political factors which have affected the transport sector: 1) an interest in expanding car ownership to the middle and lower socio-economic groups, principally through sales of the *carro popular,* and 2) an effort to lower the tax burden as part of a structural adjustment programme, thus increasing disposable incomes. Together these factors have helped to guide transport policy and to encourage increased ownership rates and vehicle use.

More specifically, the characteristics of the vehicle fleet have been affected by differentiation of tax policies for different vehicles. Given the high tax levels on imported vehicles, small levels of differentiation in rates can have significant consequences from the composition of the fleet. For instance, prior to 1992 the effective tax rate on imported cars was 300%. This has been lowered, but remained at approximately 100% for much of the last decade[1]. Receipts on vehicle taxes in 1996 totaled almost $246 million, accounting for 10% of total government income.

Perhaps the most important change in the fiscal environment in Costa Rica in recent years has been the use of the depreciation schedule in the determination of 'taxable value' which is used to calculate taxes for used vehicles[2]. The new scheme, introduced in 1986, applied a depreciation schedule differentiated according to the age of the vehicle. The depreciation rates were 20% for one-year old vehicles, 30% for two years, 40% for three years, 50% for four years, and 70% for five years or more.

In practice this policy has favoured imports of older automobiles and discouraged newer automobile imports since the depreciation schedule overstates the real rate of depreciation as reflected in pre-tax market prices. The extent to which it does so can be seen in Figure 1. The figure shows the ratio of the taxable values based upon the depreciation schedule over the taxable value based upon pre-tax market prices in 1997 for five different makes of car[3].

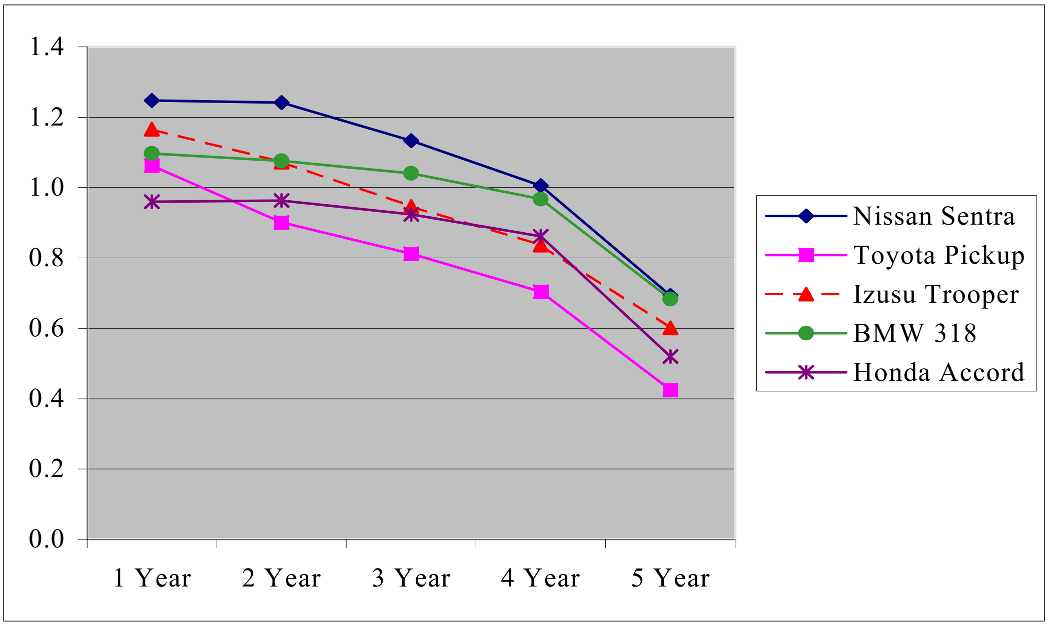
[1] Rates have since been reduced significantly to about 40%.

[2] Over time, the government has alternated between the use of the depreciated value of a used vehicle and the actual retail value ('blue book' values) in the calculation of the taxable value for some of the taxes which are applied to used cars. Currently, the depreciated value is used in the calculation of import tariffs, while the retail value is used as the basis for the other taxes.

[3] The data were obtained from the Arancel Centroamericano de Importación. Ministerio de Hacienda. Feb, 1997.

For all vehicle types, the taxable value based upon the depreciation schedule applied is less than the pre-tax market price from the second or third year. By the fifth year it is down to as low as 40% of the pre-tax market price.[4]

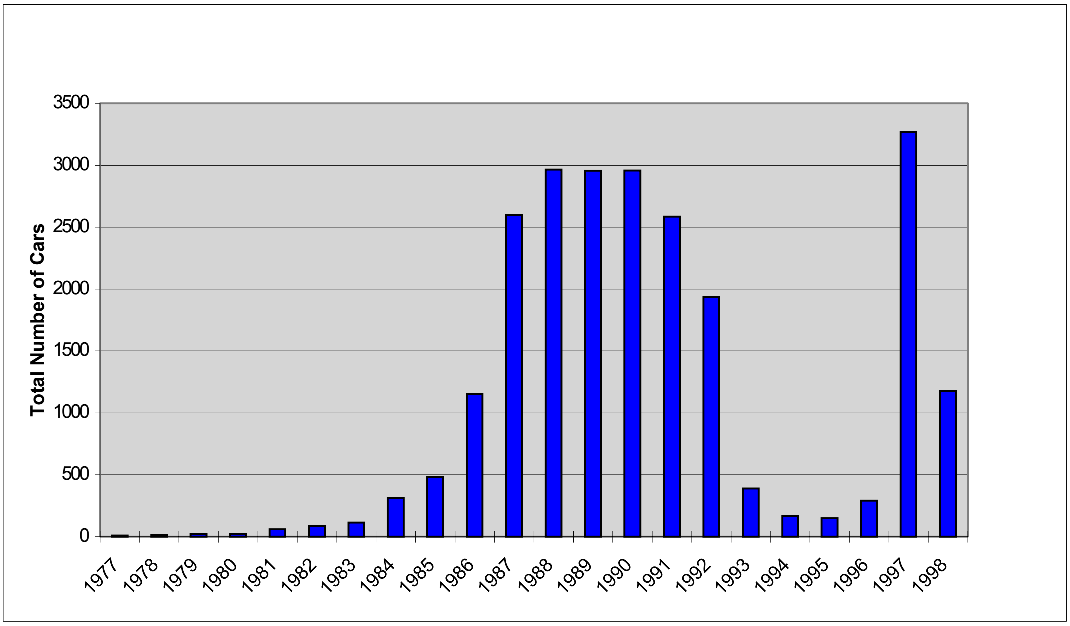
Figure 1. Taxable values based on depreciation schedules and market prices



This bias in tax rates which favours older used cars is reflected in the age composition of vehicle imports. Figure 2 shows the number of cars imported in 1997 by model year. As can be seen clearly, most imported cars are either new (1997 and 1998 model years) or older than five years.

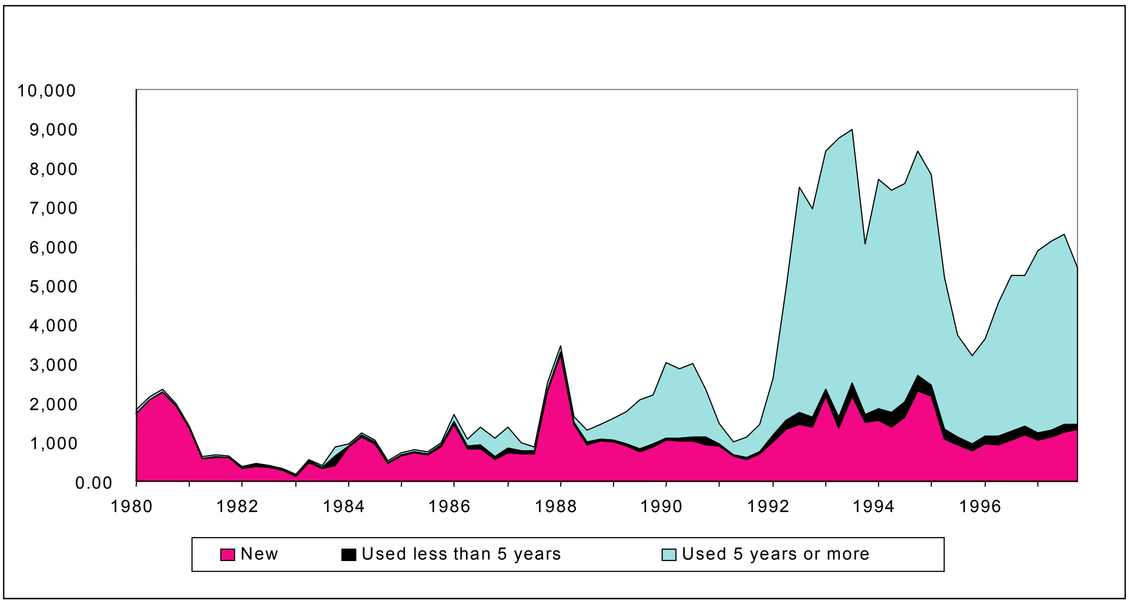
[4] Given the use of a flat 70% rate from the fifth year the ratio will start to rise again from this point, but will still be less than one for a number of years.

Figure 2. Vehicles imported in 1997 by model year



Thus, the use of the depreciation schedule to calculate taxable value appears to have had an important influence on the age composition of the vehicle stock. In fact, by 1993 the average age of the vehicle fleet was 13 years, while only 30% of the stock was seven years old or less (Valverde and Villegas 1994). Although there have been some periods where the policy has been less explicitly supportive of older used cars, in general the tendency has been to favour them. For instance, in 1990 the depreciation rate was reduced to 50% for used cars of five years old or more, in order to reduce imports of older used cars. However, the changes were declared unconstitutional in July 1991. Thus, with high tax rates and the bias in taxes toward used cars the imports of used older cars has become an increasingly important part of total imports. Figure 3 shows the imports of new, young used (< 5 years) and older used (>5 years) cars over the last two decades.

Figure 3. Vehicle imports by age class

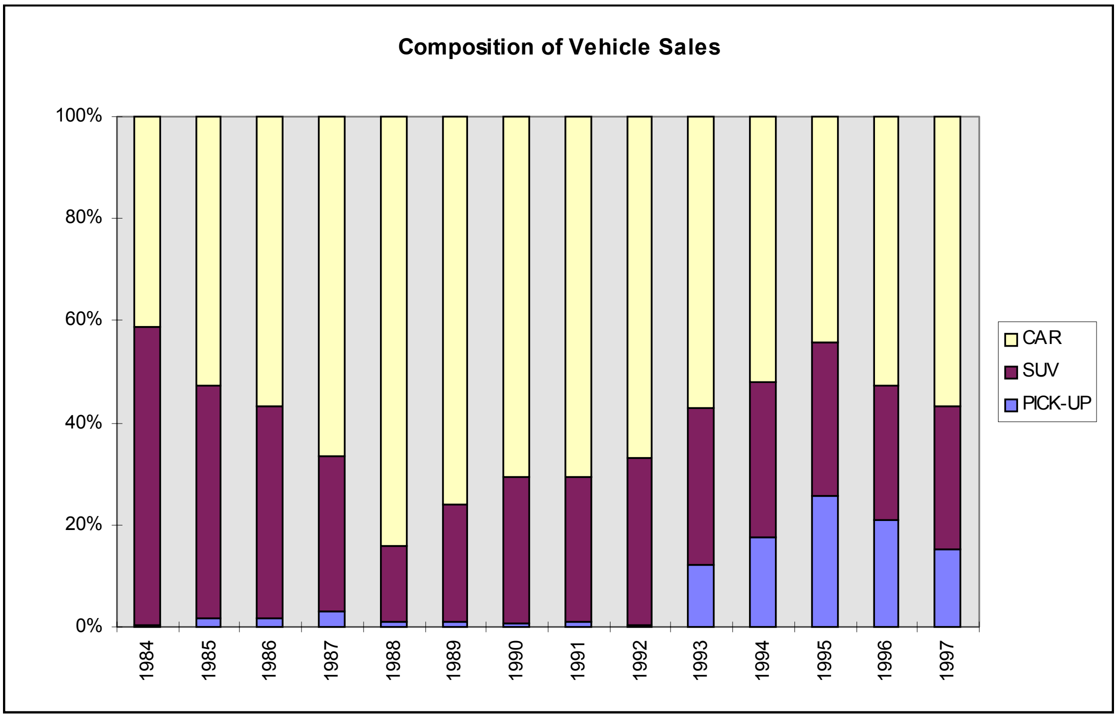


Fiscal policy has also affected the composition of the vehicle stock in terms of engine size. In particular, in June 1987 the *carro popular* policy was introduced. A car was defined as 'popular' if the engine size was not larger than 1300cc, had no leather seats and had no optional equipment, including air conditioning and luxury wheels. For such cars, significant tax preferences were granted. For example, in April 1989 cars and pick-ups with an engine size of 1300 cc and a CIF value of $4,00 had to pay a duty of 17%, along with a selective consumption tax rate of 25%. At the same time, duties for cars with an engine size of 1600 cc or more and a CIF vlaue of $6,000 were equal to 152%, plus a selective consumption tax of 75%. At the start of the programme, 'popular' cars did not have to pay the selective consumption tax at all.

Not surprisingly, the *carro popular* policy has affected the composition of vehicle sales and the average engine size of the fleet. In 1988 'popular' cars represented 93% of all vehicle imports. In 1995 that proportion had decreased to 51% (8,000 less than 1994), because both selective consumption and the *ad valorem* taxes were increased in 1994. However, between the 1995-1997 the proportion increased again, and by 1997 they represented 68% of market share.

While fiscal policy has not been particularly discriminatory with respect to 'type' of vehicle purchased, the composition of the fleet by vehicle type has also changed considerably in recent years. There has been a marked decline in the purchase of 'sedans' between the years 1988-1995 (although there was a slight reversal in this trend in 1996-1997) and a clear increase in the sale of pick-ups. Sales of 'sport utility vehicles' (a classification which includes vans, four-wheel drive vehicles. and jeeps) have been more or less constant (see Figure 4).

Figure 4. Imports of vehicles by type



Thus, the composition of the fleet in terms of vehicle age, vehicle type and engine size has certainly been affected by the government's fiscal policy. While this has important environmental implications, such measures have usually been undertaken without considering environmental impacts. On the one hand, relatively lower taxes on older used cars is likely to have increased emission rates per vehicle kilometre travelled. On the other hand, relatively lower taxes on small cars is likely to have reduced emission rates per vehicle kilometre travelled. These issues are explored in the next section.

The Environmental Consequences of Changes in the Composition of the Vehicle Fleet

In Costa Rica, as in most other countries, air pollution from transport is primarily perceived as a local phenomenon, affecting mainly urban areas. In particular, San José is experiencing rapid growth in traffic congestion and air pollution. The National Meteorological Institute and the Ministry of Environment and Energy conducted a `National Inventory of Sources and Sinks of Greenhouse Gases in Costa Rica' (1996).

For the estimation of emissions arising from mobile sources, a survey was undertaken in 1990 to estimate average annual mileage and the prevalence of catalytic converters in motor vehicles. The research was directed at both gasoline and diesel-powered vehicles, for different categories of vehicle (automobiles, jeeps, family vans, light and heavy trucks). Estimates of total emissions generated by mobile sources are shown in Table 1. These emissions result in significant ambient concentrations. Nationally, in 1990 mobile sources contributed 80.14% of total CO, 18.8% of CH_4, 99.7% of NMVOCs, 58.3% of N_2O and 87.1% of NO_x. (National Meteorological Institute, 1996).

Table 1. Emissions from mobile sources

Fuel	Emission (Gg)				
	CO	CH_4	N_2O	NO_x	NMVOC
Gasoline	162.23	0.88	0.02	7.86	29.27
Diesel Oil	10.4	0.12	0.05	18.32	3.96
Total	172.63	1.00	0.07	26.18	33.23

The National University has monitored concentrations of total suspended particulates (TSP), small particulate matter (PM-10), CO, O_3, NO_x, HCs and Pb at fixed points in San José. The concentration of TSP shows a historical upward tendency in concentrations, as well as in frequency of violations of the standard established by the World Health Organization (WHO) (Alfaro y Moreno, 1996). Recorded observations since 1993 vary from 56.4 $\mu g/m^3$ to 470 $\mu g/m^3$.

Given these trends it is not surprising to find that air pollution arising from road vehicles has become an issue of increasing concern for most Costa Ricans. Indeed, a contingent valuation survey conducted by Celis, Echeverría and Conejo (1996) for the Sistema de Ordenamiento del Gran Area Metropolitana (SOAGAM) revealed that air pollution is considered the major environmental concern for the population in the Great Metropolitan Area. More than 90% of the population believed that the air they breathe is polluted, and 80% believe that this pollution come from vehicles.

As a result of the tax policies that governments have established, purchases of vehicles are heavily weighted toward used cars, especially those more than five years of age. Furthermore, the composition of vehicle fleet is also dominated by pick-ups and small vehicles. Studies have demonstrated a relation between age, type and engine size with emission rates. For instance, Johnstone and Karousakis (1999) examine the relative emission rates for different model types using data obtained from the US Environmental Protection Agency's (EPA) National Vehicle and Fuels Emissions Laboratory in Ann Arbor, Michigan. The study finds that a number of vehicle characteristics such as engine size, vehicle weight and other factors have a significant effect on emission rates. The particular effect of vehicle age, engine size and vehicle types will be reviewed.

Vehicle age effect

As outlined above, in any given year vehicles with 5 years and more of use comprise the majority of imports in Costa Rica. The depreciation schedule applied in the country to determine import tax rates is thought to be environmentally significant because older cars are likely to produce more pollution than their newer counterparts. This is so for two reasons:

- deterioration of a given vehicle with use and age and consequent rise in pollution emission rates; and,
- reduced emission rates of new models relative to older models.

Because older cars are often thought to be more polluting than new cars, a number of countries have tried to lower the average age of the vehicle stock through scrappage bounties. These provide incentives for households to take 'older, more polluting cars off the road. For instance, under the American 'cash for clunkers' programme, stationary pollution sources are allowed to claim emission reduction credits for removing heavily polluting vehicles from service. The number of emission reduction credits earned depends on such factors as its emissions per mile and the estimated number of miles it would have been driven had it stayed in service. (Tietenberg, 1996)

Do older cars pollute more than newer cars? This issue can be examined using data obtained from the US EPA's National Vehicle and Fuels Emissions Laboratory in Ann Arbor, Michigan. The dataset used is derived from a larger database, using only observations from tests undertaken between the years 1983-1996, and using the Federal Test Procedure (FTP) which specifies conditions under which all testing must be undertaken. These are intended to simulate 'typical' driving conditions. It contains information on emissions of THCs, NO_x, CO, and CO_2 from petrol-fuelled vehicles as well as a variety of vehicle characteristics, including the testweight of each vehicle, the engine displacement, the number of cylinders, the model year, the age of the vehicle, and several others. Omitting a small number of tests with missing variables yields a total dataset of 2,850 observations.

Figure 5 presents data on emission rates for CO, THC and NOx. They appear to rise with age through to six year old cars, after which point they fall. However, to some extent this data conflates the question of model year with vehicle age, and thus are potentially misleading. For instance, the average model year for the final three age cohorts are between 1988 and 1989, while for the first six years the average model years are between 1983 and 1985. In particular the average model year for six-year old cars in the sample is 83.15, while for seven-year old cars the average model year is 89.30.

As such it is important to look at emission rates for cars of different ages of the same model year. Figure 6 is obtained by examining emission rates for 1990 model year cars (for which the largest sample is available). In this case CO, THC and NOx emission rates tend to increase more or less continuously with vehicle age, with the exception of 6-year old cars (however, there are only two observations for this age cohort). Interestingly, CO_2 emissions initially fall and then stabilise as age cohort increases.

Figure 5. Emission rates by vehicle age

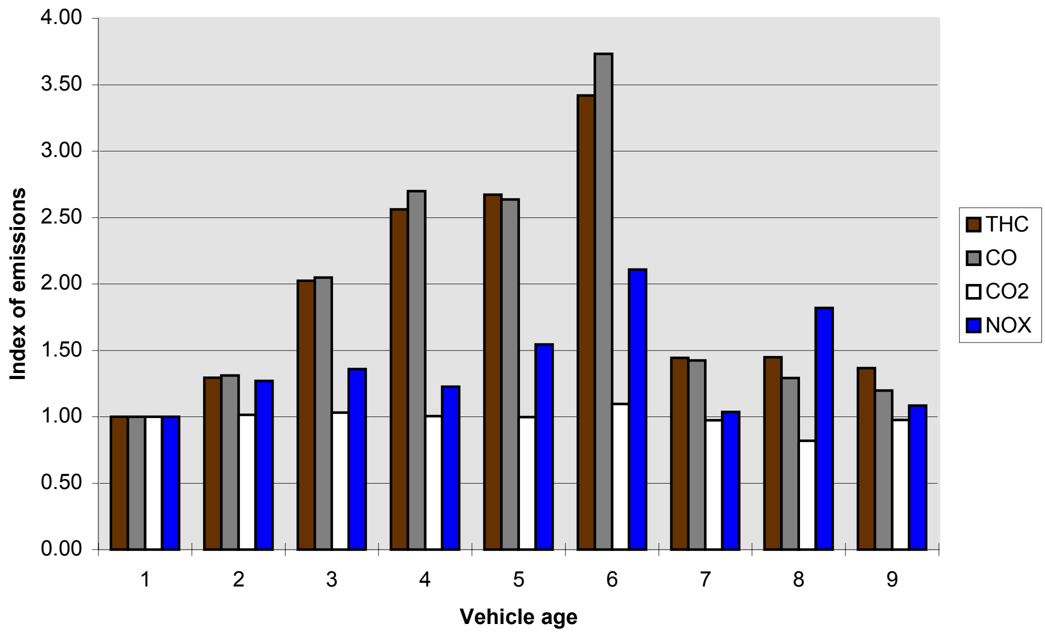
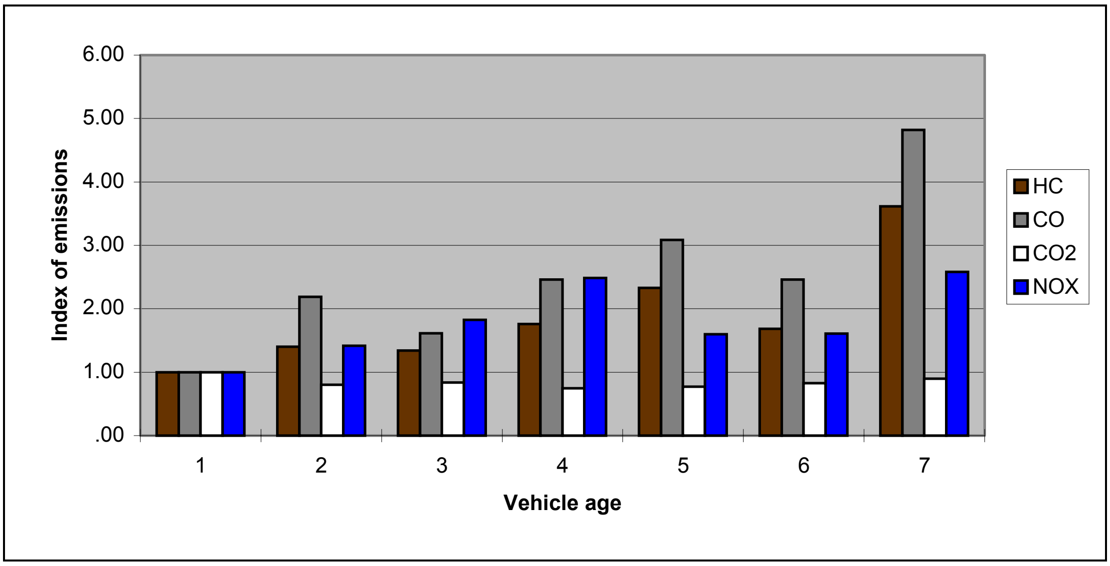


Figure 6. Emission rates for model year 1990 vehicles



Since vehicle age is highly correlated with other factors (eg, mileage), Johnstone and Karousakis (1999) examined the effect of vehicle age in the context of a more formal analysis of the determinants of vehicle emission rates. Thus, multiple regression analysis was undertaken to assess the overall significance of a number of different vehicle characteristics on emission rates. Each of the air pollutants were regressed on the explanatory variables (testweight, engine displacement, cylinders, mileage, vehicle age, engine horsepower, model year) as well as dummies for whether or not there is fuel injection and for different types of catalytic converters (oxide, threeway, oxide/threeway). Principal components analysis was applied due to the high degree of multicollinearity in the data.

Table 2 reports the estimates of the importance of vehicle age (and mileage and model year) on emissions (grams/mile) of NOx, THCs and CO (see Johnstone and Karousakis, 1999 for a full discussion of the estimation). All of the results were statistically significant, most at the 1% level, and of the expected sign. Emission rates rise with vehicle age. In the study, the effects of vehicle age, mileage and model year were estimated separately since the data were cross-sectional, including observations from a number of years.

Table 2. Determinants of emission rates

	NOx (ln)	THC (ln)	CO (ln)
Age	0.0365	0.0662	0.0892
Mileage (ln)	0.1349	0.3523	0.3420
Model year (ln)	-0.0456	-0.0618	-0.6620

Source: Johnstone and Karousakis, 1999

Engine size effect

It is also important to consider the relationship between engine size and pollution emissions. Do cars with larger engines pollute more than those with smaller engines? As in the previous case, this is also examined using data obtained from the EPA's National Vehicle and Fuels Emissions Laboratory. The environmental effects of engine size can then be examined. Table 3 shows average emission coefficients (grams/mile) for the different engine sizes. These have been weighted by proportional vehicle sales in Costa Rica in 1997-1998.

Table 3. Weighted emissions by engine size (grams/mile)

	HC	CO	NOX
Small (<2050 cc)	0.1344	0.9479	0.1948
Medium (2050 cc – 3425 cc)	0.1712	1.6817	0.2057
Large (>3425 cc)	0.2142	2.0263	0.3113

However, as with vehicle age, engine size is also likely to be very highly correlated with other vehicle characteristics. Table 4 reports estimates of the importance of engine size on emissions (grams/mile) of NOx, THCs and CO from the same study. The engine size coefficient was significant at the 1% level for all three pollutants (see Johnstone & Karousakis, 1999 for the full results). Thus, on the basis of the results, a 10% increase in engine size will result in a 1.2% increase in emissions of NOx.

Table 4. Engine size as a determinant of emission rates

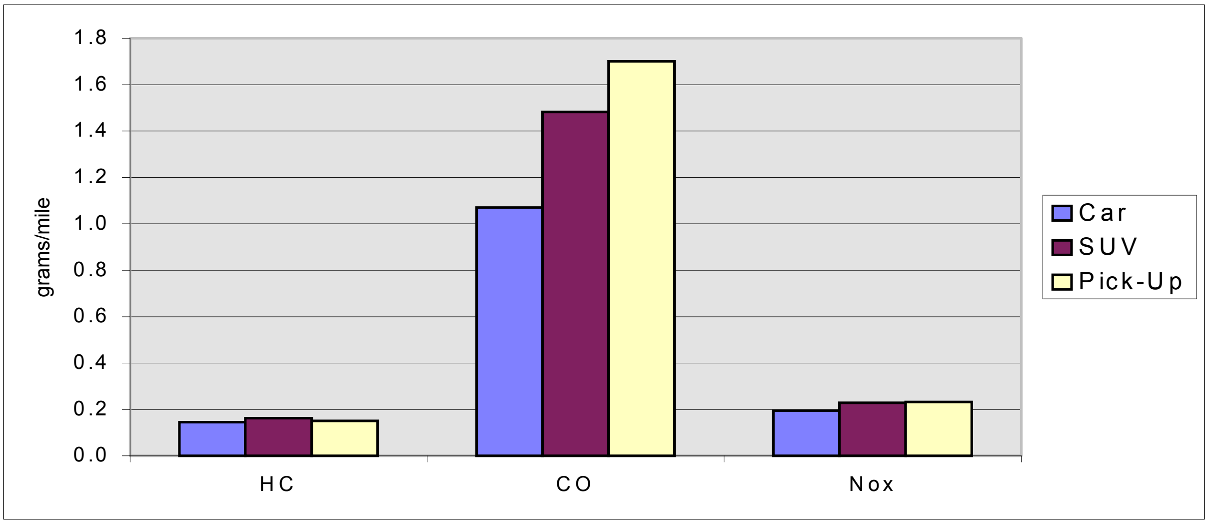
	NOx (ln)	THC (ln)	CO (ln)
Engine size (ln)	0.1216	0.1662	0.0814

Source: Johnstone and Karousakis, 1999

Vehicle type effect

The relative emission rates of different model types can also be examined using data obtained from the US EPA's National Vehicle and Fuels Emissions Laboratory. As illustrated in Figure 7, emission rates for SUVs and pick-ups are considerably higher than for 'sedans'.

Figure 7. Emission rates by vehicle type



However, this includes vehicles of all ages and model years, as well as cars which differ by emission control devices and other factors. The cross-sectional estimates of emission rates for different vehicle types was examined by using dummies for SUVs and pick-ups as explanatory variables, along with other characteristics (age, mileage, horsepower, vehicle weight, horsepower, number of cylinders, fuel injection, emission control device, etc). The results are much better for pick-ups than for SUVs. In the former case all of the coefficients are of the expected sign and statistically significant, while this is only true of CO for SUVs.

Table 5. Estimated coefficients for the effects of vehicle types on emission rates

	Nox (ln)	THC (ln)	CO (ln)
SUV	-0.053	0.043	0.149*
Pick-up	0.189*	0.476*	0.439*

The Environmental Effects of Vehicle Tax Differentiation

Due to the ease of implementation and ability to proxy for emission rates, a number of commentators have advocated the use of taxes on vehicle characteristics (see Innes, 1996 for a theoretical discussion, and Fergusson and Taylor, 1996 for a review of their application in various countries). In order to determine the environmental effects of differentiating taxes by vehicle characteristics it is first necessary to estimate the price responsiveness of consumers. The share of vehicles by the age of the car, the vehicles type and engine size are all analysed in separate models because they appear to be environmentally significant. Moreover, as discussed in Section 2, they have been used to determine import duties in the past, although not with environmental concerns in mind.

Price and quantity data for the Costa Rican vehicle fleet was obtained from the Registry of Motor Vehicles. Initially the database contained more than 500,000 records and the whole history of car imports in Costa Rica. It was later reduced to about 200,000, reducing the number of years and eliminating such kinds as ambulances, public transportation, and others. Descriptive data is presented in Table 6. Vehicles were classified according to their age, type (cars and SUVS and pick-up) and engine size. Economic and social data was obtained from the Central Bank and fuel prices from RECOPE.

Table 6. Descriptive statistics of vehicle database

	Variable name	Average	Minimum	Maximum
QN	New Cars Sales	1,122.64	314.00	3,224.00
PN	Real Price New Cars	191,464.10	145,679.45	261,966.22
PPT	Total Weighted Price (new + used)	140,309.79	75,278.48	250,626.75
QU	Sales Used Cars	2,306.24	64.00	7,385.00
PPU	Average Price Used Cars	108,320.30	45,148.21	228,047.61
QT	Total Sales (new + used)	3,428.88	401.00	8,973.00
QUA	Less than 5 years Car Sales	141.31	25.00	416.00
PUA	Real Price Less than 5 years Cars	168,089.84	115,280.77	254,547.45
QUB	5 years or more Car Sales	2,164.93	36.00	7,115.00
PUB	Real Price 5 years or more Cars	89,582.45	43,312.86	157,080.42
PIB	Real Gross Domestic Product	4,561.46	3,906.74	5,303.68
POB	Population	3,011,429	2,451,205	3,496,423
PCAP	Real Per Capita Income	13,833.39	9,824.02	17,906.52
FU	Fuel Index	97.06	60.67	282.08
TR	Real Interest Rate	15.12	4.26	26.81

The environmental effects of changes in the taxes applied to different classes of vehicle can then be simulated using coefficients derived from the 'vehicle certification' data used by the US EPA when registering vehicles for sale. This database reports the results of annual FTP tests on all vehicles. Unlike the MOBILE5 database discussed above these are not tests on vehicles in use. As such it is less reliable. However, since the MOBILE5 database does not have sufficient observations for later years, it was necessary to use the certification data in order to weight emission rates by sales of vehicles in Costa Rica in 1997. Both the estimation and the simulation were undertaken using SHAZAM (White, 1997).

New and used cars

In the first instance, the share of used cars in total vehicle sales was estimated (USEPRP). The price variable is defined as the ratio of the price of used cars to new cars (USERELP) The fuel price (FUELP) is included since historically new cars have tended to be more fuel efficient than used cars[5]. GDP per capita (GDPPC) is also included since used cars are likely to be inferior goods (at least when expressed as a share). In order to capture dynamic effects the lagged dependent variable is included (USEPRP1). All data is in log form - this is reflected by L before the relevant variable. Table 7 shows the results of the OLS estimation.

Table 7. OLS estimation of used car share

```
OLS ESTIMATION, 56 OBSERVATIONS, DEPENDENT VARIABLE = LUSEPRP
SAMPLE RANGE SET TO:      3,     58
USING HETEROSKEDASTICITY-CONSISTENT COVARIANCE MATRIX

R-SQUARE =   0.8543     R-SQUARE ADJUSTED =   0.8429
VARIANCE OF THE ESTIMATE-SIGMA**2 =  0.10727
STANDARD ERROR OF THE ESTIMATE-SIGMA =  0.32751
SUM OF SQUARED ERRORS-SSE=   5.4705
MEAN OF DEPENDENT VARIABLE = -0.91252
LOG OF THE LIKELIHOOD FUNCTION = -14.3332

VARIABLE   ESTIMATED  STANDARD   T-RATIO        PARTIAL STANDARDIZED ELASTICITY
  NAME    COEFFICIENT   ERROR      51 DF   P-VALUE CORR. COEFFICIENT  AT MEANS
LUSEPRP1  0.66951     0.1537       4.355     0.000 0.521     0.6667     0.6738
LUSERELP -0.64005     0.3068      -2.086     0.042-0.280    -0.2930    -0.4619
LGDPPC   -0.51558     0.9349     -0.5515     0.584-0.077    -0.1070     5.3844
LFUELP   -0.44381     0.5173     -0.8580     0.395-0.119    -0.1618     2.1864
CONSTANT   6.1894      10.46      0.5918     0.557 0.083     0.0000    -6.7827

DURBIN-WATSON = 1.0908    VON NEUMANN RATIO = 1.1107    RHO =  0.32132
RESIDUAL SUM = -0.46185E-13  RESIDUAL VARIANCE =  0.10727
SUM OF ABSOLUTE ERRORS=   12.276
R-SQUARE BETWEEN OBSERVED AND PREDICTED = 0.8543
RUNS TEST:   13 RUNS,   29 POS,    0 ZERO,   27 NEG  NORMAL STATISTIC = -4.3116
DURBIN H STATISTIC CANNOT BE COMPUTED
```

The Durbin-Watson indicates the presence of serial correlation. The Durbin-H statistic is much more reliable for models with lagged dependent variables, but could not be computed because of the presence of negative square roots. While Cochrane-Orcutt estimation is often used to rectify this problem, Harvey (1990) suggests the use of either Instrumental Variables (IV) estimation or Gauss-Newton (GN) estimation when lagged dependent variables are used as explanatory variables. Gauss-Newton estimation is thought to be more efficient in such cases when the sample size is small, and a routine for a two-stage estimation procedure was written based on Harvey (1990).

The Gauss-Newton results (Table 8) are relatively satisfactory, and the sign of the GDP per capita coefficient is counter-intuitive - an increase in GDPPC increases the share of used cars. (The suffix "x" at the end of the variable name refers to the transformed version of the relevant variable.) The coefficient of primary interest - the relative price variable - and all

[5] As noted above, this is due to both technological improvements with newer model years, and reduced efficiency through time for a given model year.

the other variables are of the expected sign. A 10% increase in the relative price of used cars will result in a 5.6% fall in their share of total vehicle sales.

Table 8. Gauss-Newton estimation of used car share

```
GAUSS-NEWTON ESTIMATION, 54 OBSERVATIONS, DEPENDENT VARIABLE = LUSEPRP
SAMPLE RANGE SET TO:      5,     58
USING HETEROSKEDASTICITY-CONSISTENT COVARIANCE MATRIX

R-SQUARE =   0.9879     R-SQUARE ADJUSTED =   0.9867
VARIANCE OF THE ESTIMATE-SIGMA**2 =  0.80823E-02
STANDARD ERROR OF THE ESTIMATE-SIGMA =  0.89902E-01
SUM OF SQUARED ERRORS-SSE=  0.38795
MEAN OF DEPENDENT VARIABLE = -0.85297
LOG OF THE LIKELIHOOD FUNCTION =  56.6455

VARIABLE   ESTIMATED  STANDARD   T-RATIO        PARTIAL STANDARDIZED ELASTICITY
  NAME    COEFFICIENT   ERROR      48 DF   P-VALUE CORR. COEFFICIENT  AT MEANS
LUSPRP1X  0.93882     0.3490E-01   26.90     0.000 0.968     0.6813     0.6553
LUSRELPX -0.56724     0.7625E-01  -7.439     0.000-0.732    -0.1939    -0.3120
LGDPPCX   0.51889     0.1761       2.947     0.005 0.391     0.0780    -3.9451
LFUELPX  -0.31878     0.6551E-01  -4.866     0.000-0.575    -0.0924     1.1344
RESID     0.88058     0.6853E-01   12.85     0.000 0.880     0.3088    -6.4163
CONSTANT  -8.4305      1.280      -6.589     0.000-0.689     0.0000     9.8836

DURBIN-WATSON = 1.9333    VON NEUMANN RATIO = 1.9697    RHO =  0.03327
RESIDUAL SUM = -0.21316E-13  RESIDUAL VARIANCE =  0.80823E-02
SUM OF ABSOLUTE ERRORS=   3.0730
R-SQUARE BETWEEN OBSERVED AND PREDICTED = 0.9879
RUNS TEST:   29 RUNS,   27 POS,    0 ZERO,   27 NEG  NORMAL STATISTIC =  0.2748
DURBIN H STATISTIC (ASYMPTOTIC NORMAL) =  0.25295
```

A comparison of the sales figures for used cars indicates that there is a clear distinction between used cars which are older than four years, and those which are four years or younger. Time series were constructed for these two classes of vehicle. Due to the relative dearth of price data, a reliable time-series could only be constructed for the last 9 years (36 observations)[6]. OLS estimation of share of 'old' used cars in total used car sales (GT4PRP), revealed slight negative price responsiveness. (The price variable - GT4RELP - is the ratio of 'old used' cars over 'young used' cars.) A 10% increase in the relative price of 'old' used cars relative to 'young' used cars resulted in a 0.45% decrease in their share. Surprisingly, given the structure of the equation, the Durbin-H did not reveal any indication of serial correlation.

The environmental effects of changes in the average age of vehicle purchases can now be examined by applying emission coefficients differentiated by model year. As noted above, the certification data was weighted by sales of vehicles in Costa Rica in 1997. Since the certification data is held in text files the weighting had to be done by sampling. For each year,
vehicle models were selected in descending order of frequency until 75% of the total vehicle sales for that year were achieved. However, since the vehicle model names in the EPA database did not always match the designations in the Costa Rican vehicle database, it was sometimes necessary to omit particular observations.

However, using certification data (rather than 'in use' data as in MOBILE5) ignores the effects of deterioration of the vehicle on emission rates. Since emissions tend to rise with vehicle age it is important to derive 'deterioration factors'. The estimates reported in Table 2 were applied to

[6] The price data was only considered reliable for years in which there were observations for at least ?% of the vehicles.

derive emissions of each pollutant for each model year at different ages. Weighting these figures by vehicle sales for each model year within the three vehicle classes yields the emission rates listed in Table 9.

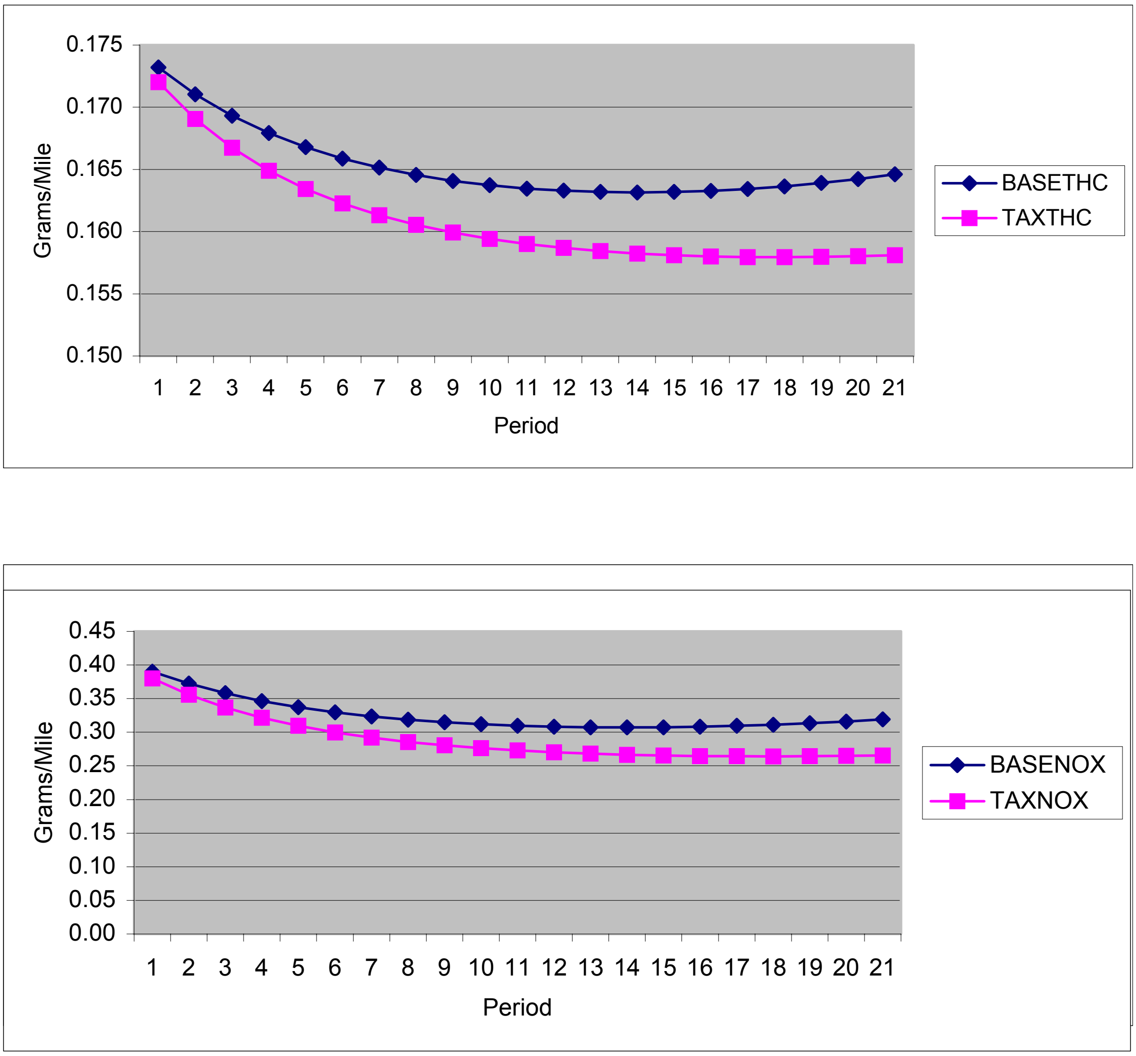
Table 9. Weighted model year emission rates (grams/mile) in 1997-1998

Emission coefficients by class			
	HC	**CO**	**Nox**
> 5 Years	0.266228	3.190625	0.559959
< 5 Years	0.259756	2.415583	0.322321
New	0.164389	1.370691	0.216033

Given the focus of the study, the only determinant of changes in emission rates from newly purchased vehicles (new and used) arises from changes in the relative shares of different classes of vehicle purchases by age class. Thus vehicle technologies are held constant from the beginning of the simulation period. Assuming that emission rates continue to improve, the results will underestimate the environmental benefits. In addition, it is assumed that substitution out of used cars is proportional to 1997 vehicle purchases.

The results are reported in terms of changes in average emission rates of new additions to the vehicle fleet. Using the estimated relative price elasticities, the effects of a tax which results in a 10% increase in the relative price of used cars to new cars is explored. All other factors are held constant, except GDP PC which is assumed to rise in accordance with trend rates (approximately 3% per annum). THCs fall by 4.0%, CO falls by 11.5% and Nox falls by 16.8% (see Figure 8.)

Figure 8. Effects of 10% increase in price of used cars relative to new cars



In a second simulation, an equivalent exercise was performed, looking at the effects of tax-induced substitution between the two classes of used vehicles (< less than 5 years and > more than 5 years). The results revealed unimportant environmental benefits (less than 1% for each pollutant). This is primarily due to the relatively small proportion of 'young' used cars (<10%), even with the higher tax.

Engine size

Efforts were also made to simulate the effects of differentiating taxes by engine size. In the first instance, it was necessary to estimate the shares of three vehicle classes, on the basis of the engine sizes outlined above (small = < 2050 cc, medium = 2050 cc - 3425 cc, large = > 3425 cc). Unfortunately, it was not possible to construct reliable time-series for vehicle prices for all three classes. As such, it was necessary to use only two shares, combining the large and medium vehicle classes. Even so, it was only possible to use 48 observations, from the first quarter of 1986 through to the last quarter of 1997.

The results of OLS estimation of the share of small cars in total vehicle sales (SMAPRP) are presented in Table 10. The price variable (SMNRELP) is defined as the ratio of the price of small cars to large cars. The fuel price (FUELP) is included since historically smaller cars have tended to be more fuel efficient than used cars[7]. GDP per capita (GDPPC) is also included since the share of smaller cars in total vehicle sales is likely to fall with relative wealth. In order to capture dynamic effects the lagged dependent variable is included (SMAPRP1). All data is in log form.

Table 10. OLS estimation of small car share

```
OLS ESTIMATION, 48 OBSERVATIONS, DEPENDENT VARIABLE = LSMAPRP
USING HETEROSKEDASTICITY-CONSISTENT COVARIANCE MATRIX

R-SQUARE =   0.8974     R-SQUARE ADJUSTED =   0.8879
VARIANCE OF THE ESTIMATE-SIGMA**2 =  0.40209E-02
STANDARD ERROR OF THE ESTIMATE-SIGMA =  0.63411E-01
SUM OF SQUARED ERRORS-SSE=  0.17290
MEAN OF DEPENDENT VARIABLE = -0.35076
LOG OF THE LIKELIHOOD FUNCTION =  66.9207

VARIABLE   ESTIMATED  STANDARD   T-RATIO        PARTIAL STANDARDIZED ELASTICITY
  NAME    COEFFICIENT   ERROR      43 DF   P-VALUE CORR. COEFFICIENT  AT MEANS
LSMAPRP1  0.73971     0.8940E-01   8.274     0.000 0.784     0.7465     0.7465
LSMARELP -0.28800     0.9026E-01  -3.191     0.003-0.438    -0.2291    -0.4692
LGDPPC   -0.21784     0.7241E-01  -3.008     0.004-0.417    -0.1702     5.9444
LFUELP   -0.42611E-02 0.1989E-01 -0.2143     0.831-0.033    -0.0057     0.0537
CONSTANT   1.8504     0.6764       2.736     0.009 0.385     0.0h000    -5.2754

DURBIN-WATSON = 1.8150    VON NEUMANN RATIO = 1.8537    RHO =  0.09119
RESIDUAL SUM =  0.64393E-14  RESIDUAL VARIANCE =  0.40209E-02
SUM OF ABSOLUTE ERRORS=   2.1585
R-SQUARE BETWEEN OBSERVED AND PREDICTED = 0.8974
RUNS TEST:   25 RUNS,   24 POS,    0 ZERO,   24 NEG  NORMAL STATISTIC =  0.0000
DURBIN H STATISTIC (ASYMPTOTIC NORMAL) =  0.80475
```

As the results presented above show, other than fuel prices, all variables are of the expected sign and statistically significant. In order to correct for heteroscedasticity, the standard errors and t-ratios are expressed using the procedure suggested by White (1980). Surprisingly, given the structure of the function, the results reveal the presence of slight negative serial correlation. The short-run price elasticity is -0.288 and the long-run price elasticity is 1.106[8]. Thus a 10% decrease in the relative price of small cars will result in an 11% increase in the share of small cars in total vehicle sales.

Given that the relative age composition of vehicles in the two classifications change through time, it was decided to confirm the results only using new vehicle sales in the two vehicle classes. This avoids the potential of confusing price effects with ‘quality’ effects, since relative prices will reflect this changing share. The results are comparable, with a short-run price elasticity of -0.233 and a long-run price elasticity 0.822.

[7] As noted above, this is due to both technological improvements with newer model years, and reduced efficiency through time for a given model year.

[8] The long-run price elasticity equals $\alpha/(1-\beta)$, where α is the short-run price elasticity and β is the estimate on the lagged dependent variable.

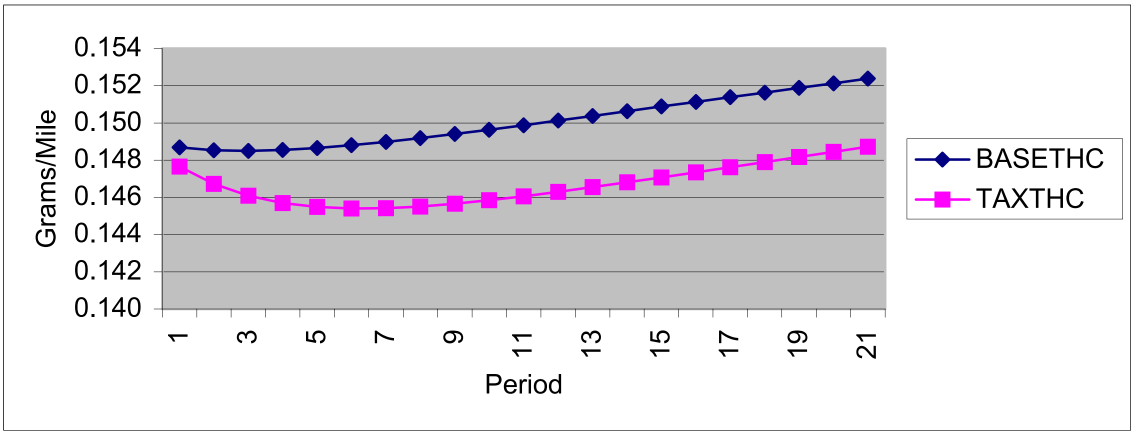
Table 11. OLS estimation of new small car share

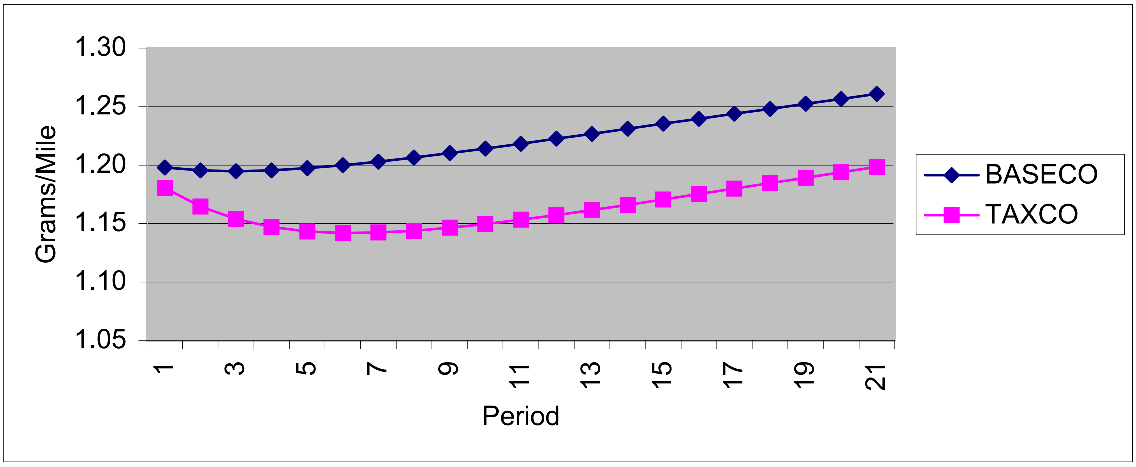
```
OLS ESTIMATION, 48 OBSERVATIONS, DEPENDENT VARIABLE = LSMNPRP
USING HETEROSKEDASTICITY-CONSISTENT COVARIANCE MATRIX

R-SQUARE =   0.8597     R-SQUARE ADJUSTED =   0.8466
VARIANCE OF THE ESTIMATE-SIGMA**2 =  0.60197E-02
STANDARD ERROR OF THE ESTIMATE-SIGMA =  0.77587E-01
SUM OF SQUARED ERRORS-SSE=  0.25885
MEAN OF DEPENDENT VARIABLE = -0.30730
LOG OF THE LIKELIHOOD FUNCTION =  57.2362

VARIABLE   ESTIMATED  STANDARD   T-RATIO        PARTIAL STANDARDIZED ELASTICITY
  NAME    COEFFICIENT   ERROR      43 DF   P-VALUE CORR. COEFFICIENT  AT MEANS
LSMNPRP1  0.71650     0.7002E-01   10.23     0.000 0.842     0.7115     0.7139
LSMNRELP -0.23293     0.9562E-01  -2.436     0.019-0.348    -0.1697    -0.4838
LGDPPC   -0.22011     0.8996E-01  -2.447     0.019-0.350    -0.1644     6.8556
LFUELP    0.37313E-02 0.2254E-01  0.1655     0.869 0.025     0.0048    -0.0537
CONSTANT   1.8536     0.8666       2.139     0.038 0.310     0.0000    -6.0320

DURBIN-WATSON = 2.3684    VON NEUMANN RATIO = 2.4188    RHO = -0.18577
RESIDUAL SUM =  0.13323E-13  RESIDUAL VARIANCE =  0.60197E-02
SUM OF ABSOLUTE ERRORS=   2.5894
R-SQUARE BETWEEN OBSERVED AND PREDICTED = 0.8597
RUNS TEST:   26 RUNS,   24 POS,    0 ZERO,   24 NEG  NORMAL STATISTIC =  0.2918
DURBIN H STATISTIC (ASYMPTOTIC NORMAL) =  -1.4719
```

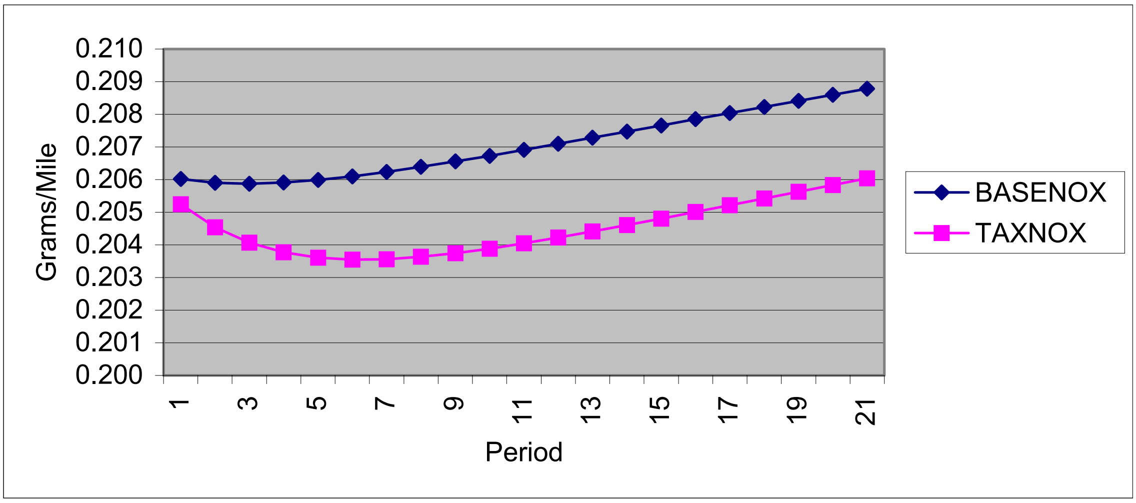
The environmental effects of differentiating taxes based on engine size can now be examined by applying emission coefficients derived from the US EPA ‘certification data’ and reported in Table 3 above. Using the estimated relative price elasticities and the emission coefficients listed above, the effects of a 10% increase in the relative price of cars with larger engines relative to cars with smaller engines is explored. Since we do not have any information on trends and determinants of emission coefficients by class, the only determinant of changes in emission rates arises from changes in the relative shares of different classes.

All other factors are held constant, except GDP PC which is assumed to rise in accordance with trend rates (approximately 3% per annum). The results are relatively significant, with emissions of carbon monoxide falling by 5.0% with a tax that generated a 10% increase in the relative price of large engined vehicles. The fall hydrocarbons is almost 2.5%, while for NOx it is just over 1.5%. (See Figure 9.)

Figure 9. Effects of 10% increase in the relative price of cars with large engines







Vehicle type

In the first instance, the determinants of the purchases of pick-ups and sport utility vehicles ('light trucks') were estimated (LTQ). Since there were relatively few observations for prices of the two types of vehicles, it was necessary to combine the two. Even then only 48 observations had a sufficiently large proportion of prices for reliable estimation. As in the other cases, a stochastic difference equation was used to try and capture some of the dynamic characteristics of vehicle purchases. The explanatory variables included were the lagged dependent variable (LTQ1), vehicle prices (LTP) fuel prices (FUELP) (since SUVs and pick-ups are less fuel efficient), and aggregate real GDP (AGGGDP). All variables are in log form. Results are shown in Table 12.

Table 12. OLS estimation of light trucks

```
OLS ESTIMATION, 48 OBSERVATIONS, DEPENDENT VARIABLE = LLTQ
USING HETEROSKEDASTICITY-CONSISTENT COVARIANCE MATRIX

R-SQUARE =   0.9236     R-SQUARE ADJUSTED =   0.9165
VARIANCE OF THE ESTIMATE-SIGMA**2 =  0.74710E-01
STANDARD ERROR OF THE ESTIMATE-SIGMA =  0.27333
SUM OF SQUARED ERRORS-SSE=   3.2125
MEAN OF DEPENDENT VARIABLE =   6.9995
LOG OF THE LIKELIHOOD FUNCTION = -3.20968

VARIABLE   ESTIMATED  STANDARD   T-RATIO      PARTIAL     STAND'D ELASTICITY
  NAME    COEFFICIENT   ERROR      43 DF   P-VALUE CORR. COEFFICIENT  AT MEANS
LLTQ1      0.795       0.075      10.61     0.000 0.851     0.7979     0.7909
LLTP     -0.609        0.354      -1.72     0.093-0.254    -0.1732    -1.0323
LAGGGDP  -0.036        0.419      -0.09     0.932-0.013    -0.0086    -0.1266
LFUELP   -0.146        0.159      -0.92     0.362-0.139    -0.0393    -0.0923
CONSTANT 10.222      13.290       0.77     0.446 0.117     0.0000     1.4603

DURBIN-WATSON = 1.4371    VON NEUMANN RATIO = 1.4677    RHO =  0.20720
RESIDUAL SUM =  0.42633E-13  RESIDUAL VARIANCE =  0.74710E-01
SUM OF ABSOLUTE ERRORS=   9.9008
R-SQUARE BETWEEN OBSERVED AND PREDICTED = 0.9236
RUNS TEST: 24 RUNS, 24 POS, 0 ZERO, 24 NEG  NORMAL STATISTIC = -0.2918
DURBIN H STATISTIC (ASYMPTOTIC NORMAL) = 1.6795
```

The results are disappointing, insofar as many of the variables are neither of the expected sign nor statistically significant. Only the lagged dependent variable and price variable are of the expected sign and statistically significant at the 5% level. However, as noted above it is recognised that OLS estimation of a stochastic difference equation is unlikely to generate consistent estimates due to the presence of serial correlation. This is confirmed by the Durbin-H statistic, which indicates the presence of serial correlation.

Following from Harvey (1990), it was decided to correct for this problem using two-stage Gauss-Newton estimation procedures rather than the usual Cochrane-Orcutt estimation. The results indicate that the problem of serial correlation has been corrected. The coefficients on the price variable and the lagged dependent variable decrease slightly. In the short-run a 10% increase in the price of SUVs and pick-ups result in a 5.5% decrease in sales. In the long run, this increases to 10.97%[9].

[9] The long-run price elasticity equals $\alpha/(1-\beta)$, where α is the short-run price elasticity and β is the estimate on the lagged dependent variable.

Table 13. Gauss-Newton estimation of light trucks

```
GAUSS-NEWTON ESTIMATION, 46 OBSERVATIONS, DEPENDENT VARIABLE = LLTQX
USING HETEROSKEDASTICITY-CONSISTENT COVARIANCE MATRIX

R-SQUARE =   0.9974     R-SQUARE ADJUSTED =   0.9971
VARIANCE OF THE ESTIMATE-SIGMA**2 =  0.16765E-02
STANDARD ERROR OF THE ESTIMATE-SIGMA =  0.40945E-01
SUM OF SQUARED ERRORS-SSE=  0.67059E-01
MEAN OF DEPENDENT VARIABLE =   5.5687
LOG OF THE LIKELIHOOD FUNCTION =  84.9377

VARIABLE   ESTIMATED  STANDARD   T-RATIO     PARTIAL     STAND'D ELASTICITY
  NAME    COEFFICIENT   ERROR     40 DF   P-VALUE CORR. COEFFICIENT  AT MEANS
LLTQ1X    0.74099     0.016       46.16    0.000 0.991     0.7461     0.7368
LLTPX    -0.54313     0.053      -10.23    0.000-0.851    -0.1499    -0.9135
LAGGGDPX  0.22537     0.078        2.90    0.006 0.417     0.0502     0.7856
LFUELPX  -0.10995     0.020       -5.60    0.000-0.663    -0.0324    -0.0688
RESID     0.94425     0.025       38.27    0.000 0.987     0.3040     1.7319
CONSTANT  -7.0833     1.720       -4.12    0.000-0.546     0.0000    -1.2720

DURBIN-WATSON = 2.0896    VON NEUMANN RATIO = 2.1361    RHO = -0.10161
RESIDUAL SUM =  0.10658E-13  RESIDUAL VARIANCE =  0.16765E-02
SUM OF ABSOLUTE ERRORS=   1.4096
R-SQUARE BETWEEN OBSERVED AND PREDICTED = 0.9974
RUNS TEST: 27 RUNS, 24 POS, 0 ZERO, 22 NEG   NORMAL STATISTIC =  0.9094
DURBIN H STATISTIC (ASYMPTOTIC NORMAL) = -0.69331
```

Given that there is likely to be a close relationship between sales of pick-ups and SUVs on the one hand, and sedan cars on the other, it was decided to estimate the proportion of the former in total vehicle sales (LTPRP). This was conducted using the lagged dependent variable (LTPRP1), the relative price of "light trucks" (LTRELP), gross domestic product per capita (LGDPPC), and fuel prices (LFUELP). All variables are in log form. The OLS estimates are presented below in Table 14.

Table 14. OLS estimation of the light truck share

```
OLS ESTIMATION, 48 OBSERVATIONS, DEPENDENT VARIABLE = LLTPRP
USING HETEROSKEDASTICITY-CONSISTENT COVARIANCE MATRIX

R-SQUARE =   0.7740     R-SQUARE ADJUSTED =   0.7530
VARIANCE OF THE ESTIMATE-SIGMA**2 =  0.35734E-01
STANDARD ERROR OF THE ESTIMATE-SIGMA =  0.18904
SUM OF SQUARED ERRORS-SSE=   1.5366
MEAN OF DEPENDENT VARIABLE =  -1.0331
LOG OF THE LIKELIHOOD FUNCTION =  14.4903

VARIABLE   ESTIMATED  STANDARD   T-RATIO      PARTIAL     STAND'D ELASTICITY
  NAME    COEFFICIENT   ERROR      43 DF   P-VALUE CORR. COEFFICIENT  AT MEANS
LLTPRP1   0.73265     0.1259       5.821     0.000 0.664     0.7309     0.7339
LLTRELP  -0.42179     0.1553      -2.717     0.009-0.383    -0.1827     0.0900
LGDPPC    0.55018     0.2982       1.845     0.072 0.271     0.2140    -5.0973
LFUELP   -0.02955     0.0829      -0.356     0.723-0.054    -0.0198     0.1265
CONSTANT -5.31720      3.000      -1.772     0.083-0.261     0.0000     5.1469

DURBIN-WATSON = 1.6408    VON NEUMANN RATIO = 1.6757    RHO =  0.17422
RESIDUAL SUM = -0.88818E-15  RESIDUAL VARIANCE =  0.35734E-01
SUM OF ABSOLUTE ERRORS=   5.4762
R-SQUARE BETWEEN OBSERVED AND PREDICTED = 0.7740
RUNS TEST: 22 RUNS, 28 POS, 0 ZERO, 20 NEG  NORMAL STATISTIC = -0.7007
DURBIN H STATISTIC (ASYMPTOTIC NORMAL) =   2.4658
```

Once again the results indicate the presence of serial correlation and thus, Gauss-Newton estimation procedures were used. As seen in Table 15, the coefficient on the relative price variable does not change appreciably. The results indicate that a 10% decrease in the relative price of pick-ups and SUVs will result in a 4.4% increase in their share of vehicle sales. In the long-run this rises to 31.32%.

Table 15. Gauss-Newton estimation of the light truck share

```
GAUSS-NEWTON ESTIMATION, 46 OBSERVATIONS, DEPENDENT VARIABLE = LLTPRP
USING HETEROSKEDASTICITY-CONSISTENT COVARIANCE MATRIX

R-SQUARE =   0.9938     R-SQUARE ADJUSTED =   0.9930
VARIANCE OF THE ESTIMATE-SIGMA**2 =  0.10540E-02
STANDARD ERROR OF THE ESTIMATE-SIGMA =  0.32465E-01
SUM OF SQUARED ERRORS-SSE=  0.42160E-01
MEAN OF DEPENDENT VARIABLE =  -1.0397
LOG OF THE LIKELIHOOD FUNCTION =  95.6123

VARIABLE   ESTIMATED  STANDARD    T-RATIO     PARTIAL     STAND'D ELASTICITY
  NAME    COEFFICIENT   ERROR      40 DF   P-VALUE CORR. COEFFICIENT  AT MEANS
LLTPRP1X  0.85999      0.025      34.59     0.000 0.984     0.7333     0.7115
LLTRELPX -0.43852      0.041     -10.59     0.000-0.859    -0.1650     0.0792
LGDPPCX   0.65325      0.060      10.97     0.000 0.866     0.2001    -4.9724
LFUELPX  -0.03744      0.012      -3.12     0.003-0.442    -0.0222     0.1310
RESID     0.96119      0.034      28.49     0.000 0.976     0.4541     4.9205
CONSTANT -0.13539      0.538      -0.25     0.803-0.040     0.0000     0.1302

DURBIN-WATSON = 1.5980    VON NEUMANN RATIO = 1.6335    RHO =  0.19349
RESIDUAL SUM = -0.25174E-13  RESIDUAL VARIANCE =  0.10540E-02
SUM OF ABSOLUTE ERRORS=  0.93743
R-SQUARE BETWEEN OBSERVED AND PREDICTED = 0.9938
RUNS TEST: 20 RUNS, 21 POS, 0 ZERO, 25 NEG  NORMAL STATISTIC = -1.1499
DURBIN H STATISTIC (ASYMPTOTIC NORMAL) =   1.3314
```

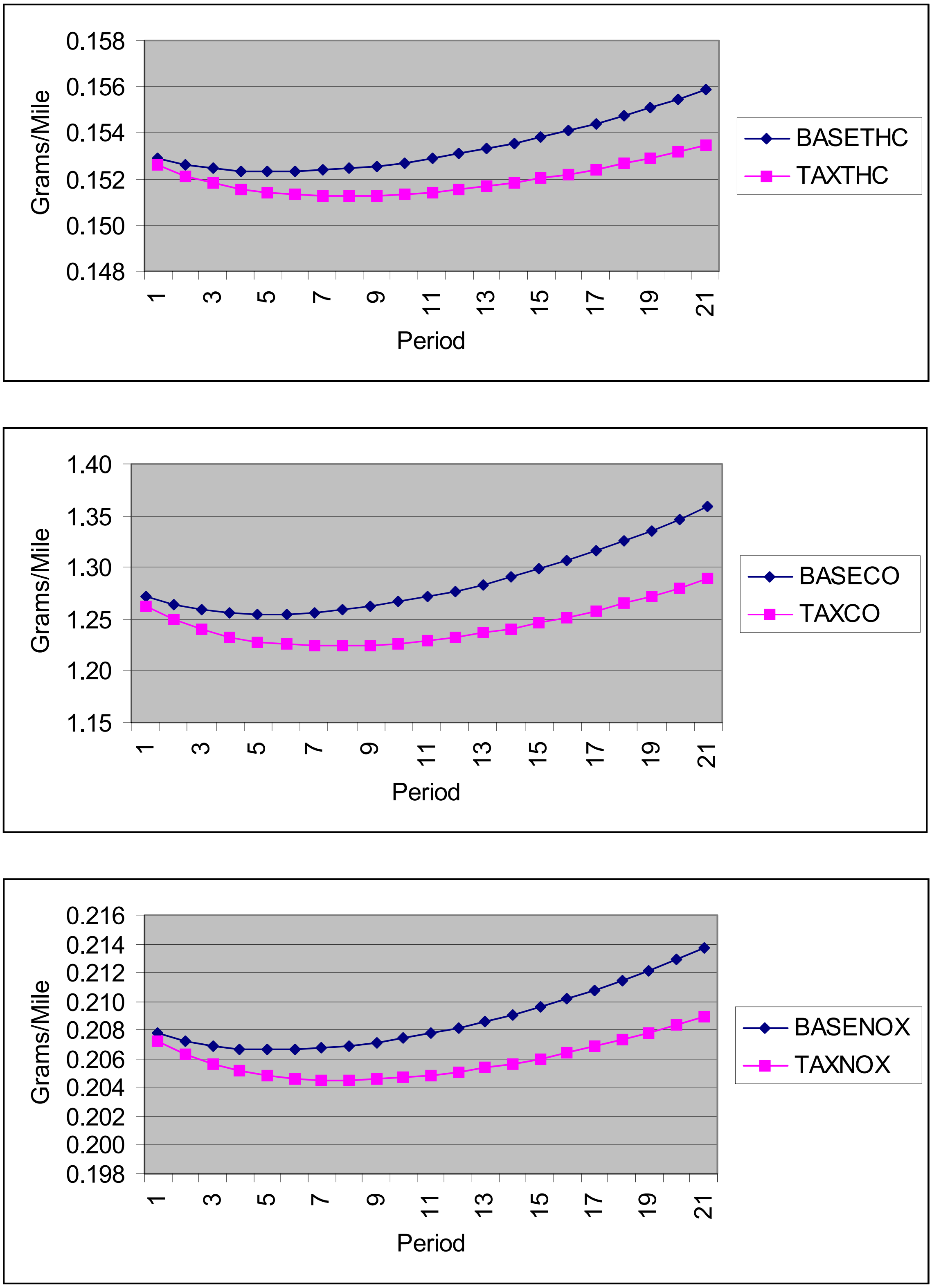
As with the cases above, the environmental effects of changes in the composition of vehicle purchases by model type can now be examined in a simulation study by applying emission coefficients differentiated by model year using the US EPA ‘certification data’ weighted by sales of new vehicles in Costa Rica in 1997. On this basis the emission coefficients (grams/mile) presented in Table 16 were obtained.

Table 16. Weighted emission coefficients by vehicle type (1997-1998 sales)

	HC	CO	NOx
Cars	0.146	1.070	0.194
SUVs & Pick-Ups	0.161	1.509	0.229

On the basis of the estimated share equations for vehicle purchases it is now possible to simulate the environmental effects of changes in relative tax rates. The only determinant of changes in emission rates arises from changes in the relative shares of different classes. Using the estimated relative price elasticities and the emission coefficients listed above, the effects of a 10% increase in the relative price of SUVs and pick-ups relative to cars is explored and shown in Figure 10. As above, all other factors are held constant, except GDPPC, which is assumed to rise in accordance with trend rates (approximately 3% per annum). The results are significant, with emissions falling by almost 1.5% for THC, 5.2% for CO and 2.2% for NOx.

Figure 10. Effects of 10% increase in the relative price of SUVs/Pick-Ups



Conclusions

This study has looked at the potential environmental benefits of differentiating taxes on the basis of vehicle characteristics. This can be done by changing the tax rate and/or the means of assessing taxable values. The extent to which such a measure would yield environmental benefits is a function of three factors:

- the existing level of tax differentiation based upon the vehicle characteristic in question;
- the relative price-responsiveness of consumers to the vehicle characteristic; and,
- the effectiveness of the vehicle characteristic as a proxy for emission rates.

In terms of environmental effectiveness, a tax which increases the relative price of used cars by 10% will reduce Nox emissions by 16.8%, CO emissions by 11.5% and HC emissions by 4.0%. The environmental effects of other means of differentiation (engine size and vehicle type) are much weaker. Moreover, since the present tax in Costa Rica is biased in favour of used cars, the case for 'neutralising' this bias on environmental grounds is likely to be stronger on efficiency grounds. In contrast, small cars (which are less polluting) are already favoured by the existing tax regime.

However, it should be emphasised that part of the motivation for favouring both used cars and small cars is distributional. Relatively poorer households have tended to buy smaller used cars and a change in the tax rate, or an adjustment in the depreciation schedule, which increases the relative price of smaller used cars is likely to be regressive, at least for car-owning households. However, there are better ways to achieve distributional objectives than to apply taxes which favour the import of used cars, particularly since the poorest are not likely to own a car of any sort.

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☐ **Mangroves or Fishponds? Valuation and Evaluation of Alternative Uses of a Mangrove Forest in the Philippines.** Ron Janssen & Jose Padilla. September 1997. 258 pages. £25.

One of the major threats to mangroves in the Philippines is the rapidly increasing aquaculture industry. This study includes a review of valuation methodologies and their application to the case study area of the Pagbilao experimental mangrove forest in the Philippines. Valuations of goods and services and environmental functions of the forest are employed to assess alternative management regimes using both cost-benefit analysis as well as a multi-criteria approach. Much depends on the management objectives: conversion to aquaculture is the most economically efficient management option. However, if equity and sustainability objectives are included, commercial forestry is the preferred alternative.

☐ **Incentives for Eco-Efficiency. Market Based Instruments for Pollution Prevention: A Case Study of the Steel Sector**. Ritu Kumar, Nick Robins, A.K. Chaturvedi, R. Srinivasan and J. Gupta. December 1997. 96 pages. £20.

Mounting pressures on industry to reduce pollution, to remain globally competitive and to meet the requirements of international standards, require fundamental changes in government policy and corporate approaches to environmental management. This report presents the results of an international study assessing the potential for market-based instruments for pollution prevention in the steel sector in India. It recommends a set of policy measures to reduce discharge levels in the most cost effective manner, to induce firms to adopt cleaner technologies and to encourage firms to economise on energy and water resources. In this regard, the importance of achieving coherence with existing policies, building trust among key stakeholders and gradually phasing in market-based instruments is emphasised.

☐ **Economic Incentives for Watershed Protection: A Case Study of Lake Arenal, Costa Rica**. Bruce Aylward, Jaime Echeverria, Alvaro Fernandez Gonzalez, Ina Porras, Katherine Allen, Ronald Mejias. February 1998. 323 pages. £30.

Conventional wisdom holds that cutting down tropical forests for livestock production is not only bad business but bad for the environment. In particular, it is thought that conversion of natural forest to pasture leads to a rise in the sedimentation of waterways and resevoirs, increased risk of flooding and loss of dry season water supply. In the case of Lake Arenal, Costa Rica, this conventional view is stood on its head by research showing that ranching, dairy farming and associated downstream hydrological effects represent important positive values to the Costa Rican economy, values that significantly outweigh expected returns from reforestation

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