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Emissions-Based Vehicle Tax Reform for Cyprus: A Simulation Analysis

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Tryfonas Christodoulou and Sofronis Clerides

Executive Summary

Several policy tools are being employed or debated as possible ways of curbing carbon emissions in the transportation sector. One such instrument is the taxation of vehicle purchases, often in the form of feebates. We estimate a model of demand for automobiles in Cyprus and simulate scenarios under which (i) a feebate scheme is introduced in addition to existing taxes and (ii) the existing consumption tax is completely replaced by an emissions-based tax. The analysis provides a useful quantification of the tradeoffs between government revenue, consumer welfare from vehicle use and environmental harm from emissions.

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Φορολογία οχημάτων με βάση τις εκπομπές ρύπων: Προσομοιώσεις για την Κυπριακή αγορά

Τρύφωνας Χριστοδούλου και Σωφρόνης Κληρίδης

ΠΕΡΙΛΗΨΗ

Διάφορα εργαλεία πολιτικής εφαρμόζονται ή συζητούνται ως τρόποι μείωσης των εκπομπών ρύπων στον τομέα των μεταφορών. Ένα από αυτά είναι η φορολόγηση της αγοράς νέων οχημάτων στη βάση των ρύπων, συχνά υπό τη μορφή συνδυασμού φόρου/επιδότησης. Η παρούσα μελέτη προβαίνει σε οικονομετρική εκτίμηση της ζήτησης για αυτοκίνητα στην Κύπρο και προσομοιώνει δύο κύρια σενάρια. Σο πρώτο σενάριο εφαρμόζεται ένα σχέδιο φόρου/επιδότησης επιπλέον των υφιστάμενων φορολογιών. Στο δεύτερο σενάριο η βάση του υφιστάμενου φόρου κατανάλωσης μετατοπίζεται από τον κυβισμό στους ρύπους με ένα εισοδηματικά (για το κράτος) ουδέτερο τρόπο. Η ανάλυση παρέχει μια χρήσιμη ποσοτικοποίηση των επιπτώσεων των διαφόρων εναλλακτικών σεναρίων στα κρατικά έσοδα, την ευημερία των καταναλωτών και το περιβαλλοντικό κόστος των ρύπων.

1. INTRODUCTION

Transportation is globally the largest final energy consuming sector and therefore the largest producer of carbon emissions. The sector is also growing; if current trends continue, the sector's carbon emissions are expected to rise by 50% by 2030 and by over 80% by 2050 (International Energy Agency, 2009). This increase essentially cancels out any progress toward limiting carbon emissions in other sectors of the global economy. There is now wide consensus that carbon emissions from the transportation sector need to be curbed substantially in order to successfully address the risks associated with global warming.

The use of fossil fuels imposes a social cost that is not reflected in their market price. This is a classic case of a negative economic externality that can be corrected using a Pigouvian tax, which is a tax on the activity causing the externality. Economists have indeed strongly advocated the imposition of a carbon tax as a way of correcting this market failure. In the current political and economic climate, however, the carbon tax is difficult to implement as it faces strong resistance from voters. Moreover, one could plausibly argue that fuel taxes in Europe are already quite high and may already account for the externality cost.

The difficulty of implementing the carbon tax has led policy makers to consider alternative approaches. A policy instrument that has gained particular attention in recent years is the feebate. A feebate is a combination of a fee and a rebate and it is levied on the vehicle at the time of purchase. If a vehicle's carbon emissions exceed a certain level, the buyer pays a fee; if emissions are below that level, the buyer receives a rebate. Thus, the scheme changes the relative prices of fuel-efficient vehicle versus gas-guzzlers and therefore gives consumers an incentive to switch from the latter to the former. A key advantage of a feebate scheme is that it can be designed to be revenue-neutral, which makes it much more palatable politically. Feebate schemes are currently implemented nationwide in Canada and France and to some extent in other European countries such as Denmark, the Netherlands and Norway.[1]

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[1] See the review of Bunch, Greene, Lipman, Martin and Shaheen (2011). Empirical studies of North American markets have been conducted for several years, with European studies following more recently; see Adamou, Clerides and Zachariadis (2012a) for an up to date literature review.

Automobile taxes in Cyprus are very high and constitute a significant source of government revenue. Several different taxes and fees are levied, the largest one being a consumption tax that is a function of the vehicle's engine capacity.[2] Emissions first entered the tax calculation in 2006 in the form of a discount in the consumption tax for low-emission vehicles. In recent years there has been talk of switching the base of the consumption tax from engine capacity to emissions in order to promote the use of more fuel-efficient vehicles.

The aim of this paper is to simulate the effects of introducing emission-based taxation of automobiles in Cyprus. This is accomplished by first estimating a differentiated product demand system for automobiles using data from 2006-2008. The system is then used to simulate the impact of different feebate schemes on vehicle sales, consumer welfare and carbon emissions. We focus on revenue-neutral schemes, as we believe those are more likely to be implemented.

We consider two possible scenarios. We first examine the effects of introducing a symmetric linear feebate while leaving existing taxes as is. We consider this as the baseline scenario because it will introduce relatively mild price adjustments. We then consider the case where existing taxes are completely abolished and are replaced by a carbon-based tax schedule. The change of the tax base leads to large price swings for some models. It turns out that a linear tax schedule cannot be revenue-neutral. This is not surprising as the current tax scheme places a heavy penalty on large vehicles. In order to achieve revenue neutrality we introduce three tax schemes in the form of step functions with an increasing marginal tax rate. We examine several tax/feebate schemes under each scenario and measure the impact on the variables of interest in each case.

The analysis provides a useful quantification of the tradeoffs between government revenue, consumer welfare from vehicle use and environmental harm from emissions. Our findings can be used to guide the design of new tax schemes that will achieve policy objectives at the lowest possible cost for society.

[2] This has been the case since 2003. Prior to that, the consumption tax was ad valorem, calculated as a percentage of the vehicle's import price.

2. FEEBATES

The general idea of the feebate is to change relative prices by charging a fee to high-emission vehicles and offering a rebate to low-emission vehicles. This basic principle can be implemented in many different ways. A simple form is the *symmetric linear feebate*:

$$F = t(CO_2 - PP)$$

The amount of the feebate, *F*, depends on the vehicle's carbon emissions (CO_2), a pivot point *PP*, and a tax rate *t*. *PP* and *t* are policy variables to be set by the government. Vehicles with emissions above *PP* pay a fee while those with lower emissions receive a rebate. The parameter *t* is the rate at which deviations from *PP* are penalized (if they exceed *PP*) or subsidized (if they are below *PP*). The rate is independent of the total amount emitted by the vehicle (linearity) and is the same regardless of whether it is a tax or a subsidy (symmetry). With a symmetric scheme, the pivot point *PP* has to be near the middle the observed range of emissions in order for revenue-neutrality to be feasible.

The symmetric linear feebate is just one of many schemes that could be implemented. Nonlinear schemes that penalize (reward) more heavily vehicles with very high (low) emissions might also be considered. Asymmetric schemes can have different rates for taxes than for subsidies; those might be useful if one wants to set a pivot point that is not near the middle of the current range. A step function could be introduced instead of a continuous scheme, where vehicles would be divided into categories on the basis of emissions and appropriate fees/rebates would be set.

Despite the multitude of possibilities, the linear tariff has several features that make it an attractive option. It is simple and transparent, and therefore less likely to be manipulated by special interests. Most importantly, linear feebates can be justified on economic grounds. The point of a Pigouvian tax is to incorporate the social cost of an activity into the price of the output. The social cost of each gram of CO_2 released into the atmosphere by a certain vehicle is the same regardless of the total number of grams released by that same vehicle. Hence the tax required to correct the externality should be independent of the vehicle's total emissions.

A wide array of different feebates schemes have been implemented in practice. Pure symmetric linear schemes are uncommon. Several countries use asymmetric schemes with a linear tariff above the pivot point and a zero rebate. Some countries use various other forms of piecewise linear tariffs or step functions.[3] Clearly the range of possibilities is very large and each country can choose a scheme that addresses its particular goals.

Ireland makes an interesting case study because it implemented a similar policy change as the one we are considering here. In July 2008 Ireland changed the tax base from engine size (cc) to the CO_2 performance of cars (g/km). Rogan, Dennehy, Daly, Howley and Gallachóir (2011) report that (weighted) average new vehicle CO_2 emissions before the introduction of the new taxation was around 165 g/km, much higher than the EU target of 130g/km. Their ex ante analysis shows that in the first year of the new taxation system the average specific emissions of new cars fell by 13% to 145 g/km. This was mostly due to consumers shifting to more efficient cars rather than to smaller (in terms of engine size) cars. The down side of the Irish reform was that it led to a decrease in public revenues.

3. DATA

Data for the period 2006-2008 were obtained from two sources. The Cyprus Road Transport Department (RTD) provided data on automobile registrations, including several attributes of registered vehicles (engine capacity, dimensions, weight, etc.) Information on vehicle prices was obtained from the monthly magazine 4Τροχοί (4Wheels). Prices are reported at the model variant level, along with several attributes of each variant. The two data sources were matched into one dataset where an observation is defined by the model name, fuel type and engine capacity. That is, vehicles which differ in one of the above attributes are recorded as two different observations. Table 1 presents descriptive statistics for key variables.

Vehicle models were divided into five groups on the basis of engine capacity**.** Table 2 presents CO_2 emissions and prices by group. As expected, cars with greater engine capacity have higher CO_2 emissions on average. What is noteworthy is that some vehicles belonging to a smaller class have higher CO_2 emissions compared to *average* CO_2 emissions of vehicles belonging to a larger class. This suggests that there is significant scope for emissions reduction with a tax policy that induces

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[3] See Braathen (2012).

consumers to switch from high-CO_2 to low-CO_2 vehicles *within* their preferred class. Table 3 further breaks down CO_2 emissions by fuel type: diesel, gasoline and hybrid (dual propulsion). Vehicles with diesel engines are on average less polluting than gasoline-powered vehicles in the same class.

Table 1: Descriptive Statistic of key variables (obs: 512)

Stats	Engine capacity (cc)	CO_2 emissions (g/km)	Horse power	Length (m)	Prices (€ 2006)
Min	995	100	38	2.727	7,708
5%	1,150	116	50	3.588	10,155
25%	1,390	145	66	4.055	13,733
50%	1,596	164	80	4.342	18,529
75%	1,984	190	107	4.598	32,244
95%	2,987	267	171	4.89	80,231
Max	4,196	493	353	5.243	153,729
Mean	1,724	174	91	4.328	27,263
St dev.	527	46	40	393	23,092

Source: Based on data from Road Transport Department and the magazine 4Τροχοί (4Wheels).

Table 2: Descriptive Statistics of key variables by vehicle class

Class	Obs.	CO_2 emissions			Price		
		Mean	Min	Max	Mean	Min	Max
City	29	127	109	156	9,897	8,581	11,907
Small	139	146	99.5	201	13,900	7,708	31,224
Medium	175	161	102	249	18,590	9,244	28,432
Large	113	194	145	251	36,428	23,337	54,891
Luxury	56	263	173	493	78,211	19,494	153,729

Table 3: CO_2 emissions by group and subgroup

		CO_2 emissions g/km		
Group	Subgroup	Mean	Min	Max
City	Gasoline	127	109	156
Small	Diesel	140	109	165
Small	Hybrid	111	109	115
Small	Gasoline	148	100	201
Medium	Diesel	131	106	186
Medium	Dual Proportion	102	102	102
Medium	Gasoline	168	130	249
Large	Diesel	185	146	247
Large	Gasoline	198	145	251
Luxury	Diesel	244	173	309
Luxury	Gasoline	291	173	493

4. DEMAND ESTIMATION AND POLICY SIMULATIONS

4.1 Methodology

Demand for automobiles was estimated using a two-level nested logit model of demand for differentiated products. This type of model is commonly used in the literature to estimate demand for automobiles. While not as general as a full random coefficients model, the nested logit allows for the estimation of reasonably rich substitution patterns at a substantially lower computational burden. Full details on the model and estimation can be found in Adamou, Clerides and Zachariadis (2012a).

With the estimated demand system in hand, one can proceed with policy simulations. Given a specific feebate scheme the amount of tax (rebate) each vehicle will pay (receive) can be calculated. This requires an assumption on how prices will respond to the introduction of the scheme. There are two possibilities. The first is to assume that firms are engaged in a differentiated product pricing game. Based on this, one can then proceed to solve for the new (post-feebate) Bertrand-Nash equilibrium prices under that assumption. The primary advantage of this approach is its firm theoretical grounding. There are two disadvantages. One is that the conduct assumption cannot really be tested and there is the risk of imposing an incorrect restriction. The second disadvantage is that the calculation of optimal prices involves some computational cost.

The alternative approach is to assume that taxes will be completely passed through to final prices. This assumption is on murkier theoretical grounds but empirical evidence indicates that tax pass-through is often close to 100%.[4] We believe that in the short-run - which is the scope of our analysis - this may be a reasonable approximation of reality, perhaps more so than the assumption of Bertrand-Nash pricing. This is clearly another assumption that is also not testable. Nonetheless, we take comfort from the work of Adamou, Clerides and Zachariadis (2012a, 2012b) that used both approaches in the cases of Germany and Greece and found little difference in the final outcome.

Once post-feebate prices have been determined, it is straightforward to compute the sales of each model in each hypothetical scenario and the impact of the feebate on consumer welfare, seller profits, government revenue and emissions. In the rest of this section we present and discuss the simulation results. Parameter estimates from the two-level nested logit model are provided in the Appendix.

4.2 The impact of a symmetric linear feebate

We first consider the introduction of a symmetric linear feebate on top of existing taxes. Three different pivot points (120, 140 and 160 g/km) and four different feebate levels (15, 30, 45 and 60 euro per g/km) where used, resulting in twelve different feebate schemes. Figure 1 shows the distribution of new vehicle sales by CO_2 emissions class for each tax rate with a pivot point of 140 g/km. The bottom bar shows actual sales and higher bars show the distribution of sales at different tax rates. As the feebate becomes more stringent (*t* rises), the sales of low-emission vehicles rise at the expense of high-emission vehicles. The actual share of cars emitting less than 160 g/km in 2008 is 40.48%. The share increases with *t*, exceeding 50% when *t=60*. Figure 2 is a similar picture that breaks down sales by vehicles class rather than emissions class. Smaller cars gain market share as the feebate become more stringent because on average they have better fuel economy and lower emissions than larger cars. The figures above show that the

[4] See Poterba (1996) and Besley and Rosen (1999).

model's predictions of the impact on vehicle sales are quite sensible and give us confidence about the appropriateness of the model.

Figure 1: Impact of feebate on the distribution of new vehicle sales by vehicle class

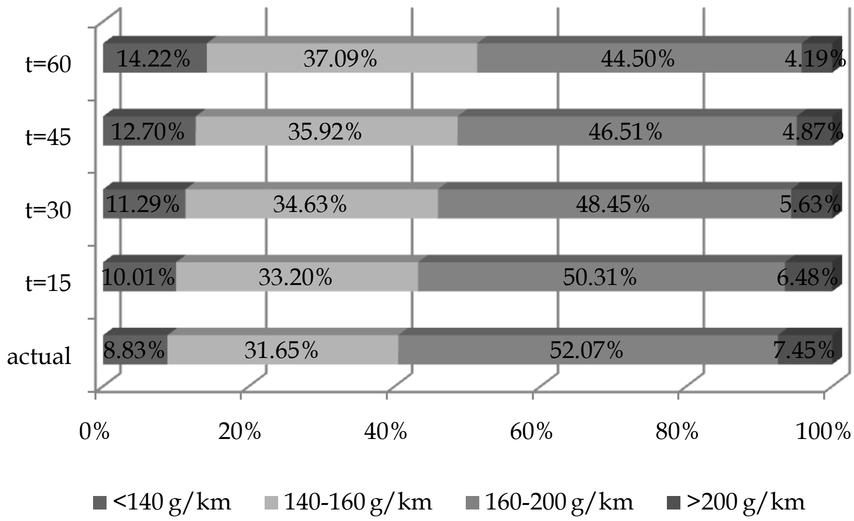

Figure 2: Impact of feebate on the distribution of new vehicle sales by CO_2 emission class

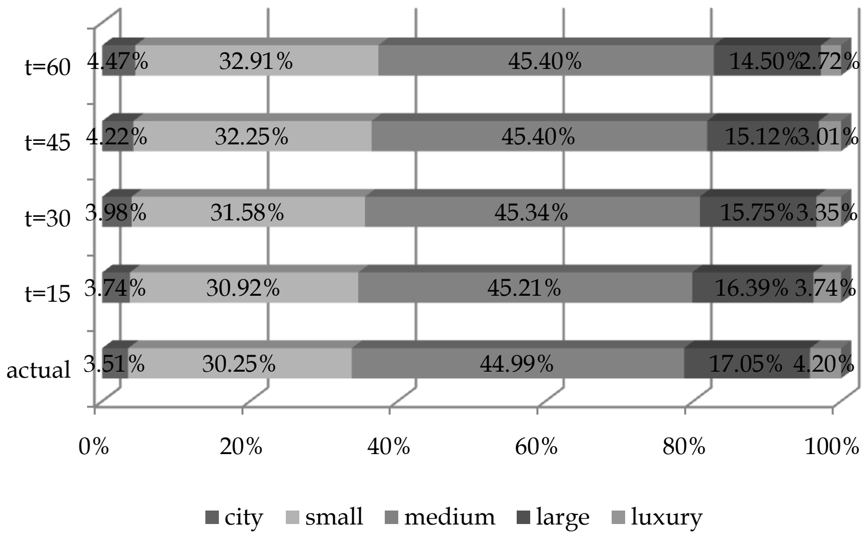

Table 4 reports changes in public revenues, consumer welfare, profits and emissions associated with each feebate scheme. The results highlight the tradeoffs associated with the choice of a policy. Keeping the pivot point fixed, increasing the tax rate leads to a decrease in profits, consumer welfare and emissions. This is the major tradeoff: a bigger reduction in emissions is associated with a bigger loss of consumer welfare (and profits). This correlation is stronger when the pivot point is low. The reason is that a low pivot point means that large shifts in consumer purchases are required in order to bring emissions down. The same patterns are observed in the case of profits, as might be expected. High taxes are effective in reducing emissions but they hurt both producers and consumers. Note that the change in emissions is in comparison to emissions from actual 2008 new vehicles sales, which amounted to 50,525 tonnes. The most stringent feebate we consider (t=60, PP=120) reduces new vehicle emissions by 23.7%.

The impact of a feebate scheme on public revenue is an important aspect, as schemes that lead to increased tax receipts may be politically unacceptable. Table 4 shows that a high pivot (160 g/km) has a large negative impact on public revenues because many rebates are given out. A more moderate pivot also has a negative impact on revenues, but much smaller in magnitude. With a pivot of 120 g/km the feebate increases revenues. These numbers suggest that if revenue neutrality is important, the pivot point must be in the range 120-140.

In order to obtain a dollar value on the total welfare effects of each scheme we need to calculate the value of reducing CO_2 emissions. We assume that each car travels 15,000 kms per year. The social cost of carbon is measured in euro/tonne. We carry out the calculations using an estimate of the social cost of 15 euro/tonne, which is in the range of estimates typically used in the literature. It is easy to repeat the calculations using alternative figures if necessary. The total welfare impact is shown in the last column of Table 4. All schemes result in a reduction of total welfare. This is because the welfare gain from the reduction of CO_2 emissions is at least an order of magnitude smaller than the welfare loss to consumers and producers. For reasons mentioned above, the higher the tax rate *t,* the greater the decrease in total welfare since consumers avoid buying new cars at these prices and profits are lower due to lower demand.

TABLE 4: Simulated impacts after the introduction of a linear feebate

Scenario		Change in:				
Pivot Point	Feebate (euro)	Public revenues[1]	Consumer welfare[1]	Profits[1]	CO_2 emissions[2]	Total welfare[1] (SCC[3] = 15)
	15	1.9	-2.2	-5.9	-3,564	-6.2
	30	3.1	-4.1	-11.2	-6,697	-12.1
	45	3.5	-5.7	-15.9	-9,490	-18
120	60	3.2	-7.1	-20.1	-11,998	-23.9
	15	-1.2	-1.3	-2.7	-2,384	-5.1
	30	-2.7	-2.4	-5.6	-4,460	-10.7
	45	-4.6	-3.4	-9	-6,299	-16.8
140	60	-6.8	-4.2	-11.1	-7,941	-22
	15	-4.6	-0.3	-0.1	-1,176	-5
	30	-9.3	-0.5	-0.6	-2,117	-10.4
	45	-14.5	-0.6	-1.5	-2,878	-16.6
160	60	-20.2	-0.6	-1.3	-3,490	-22.1

Notes: [1] Expressed in million euros; [2] Expressed in tonnes; [3] SSC refers to Social Cost of Carbon in euro/tonne.

4.3 Substitution of consumption tax with emissions-based tax

We now consider the case where the existing consumption tax is completely scrapped in order to be replaced by an emissions-based tax designed to generate the same revenue. The data presented in Table 2 indicate that vehicles with similar engine size (and therefore similar consumption tax burden) can have quite different emission levels. This implies that the change of the tax base from engine capacity to emissions will result in significant shifts in prices and, by extension, market shares and emission levels.

The existing consumption tax is highly nonlinear. The tax rate is €0.51 per cubic centimeter (cc) for vehicles with engine capacity up to 1650 cc. It jumps to €3.42 per cc (applied to the total number, not the increment) for engine capacities in the range 1651-2250, to €5.98 for the range 2251-3000 and to €7.69 for engine capacities over 3000cc. A discount or surcharge is then applied depending on emissions: 30% discount for vehicles emitting less than 120 g/km, 20% discount for 120-165 g/km, 10% discount for 165-200, 10% surcharge for 200-250 g/km and 20% surcharge for emissions exceeding 250 g/km.

It is not possible to reproduce the revenue generated by this tax with a linear emissions tax. We therefore devised three nonlinear tax schedules with increasing marginal rates, as displayed in Table 5. Policy A is the baseline case. Policy B differs in how it taxes models with low to mid-range emissions, while policy C heavily penalizes vehicles with very high emissions. As with the existing consumption tax, the rates apply to total emissions and not just increments. For example, with policy C the total tax for a vehicle emitting 170 g/km will be 170 g/km * €7 per g/km = €1190.

Table 5: New vehicle consumption tax rates (introduction of emission-based tax)

CO_2 emissions	Policy A	Policy B	Policy C
<160	2	2.4	3
160-180	7	6.1	7
180-220	38	42	43
220-300	85	86	85
>300	90	90	150

Notes: CO_2 emissions are in g/km; tax policies are in euro per g/km.

Table 6 presents a comparison between the existing consumption tax and the three new tax policies in terms of the tax levied on different models. Vehicles with emissions below 180 g/km will generally pay a lower tax than they currently do, while those with higher emissions will face a greater tax liability. Because of the change in the tax base, individual models with large engine capacity but low emissions will benefit greatly, while models with small engine capacity and high emissions will be heavily penalized. For example, one particular model in our data that emits between 160-180 g/km is currently paying a consumption tax equal to €12,964.80 because of its engine capacity. With the new taxation this car will pay a maximum of €1,247.50, meaning a reduction in tax of €11,717.

Figure 3 shows the distribution of new car sales by CO_2 emissions class before and after the introduction of each of the three policies. There is a notable shift towards cars with CO_2 emissions below 160g/km. The market share of these two categories in 2008 was 40.48%; it would increase to around 50% after the introduction of any of the three tax policies. Figure 4 shows the distribution of sales by vehicle class. The most important thing to note is that the distribution does not change much after the change in the tax base. This is related to the point made earlier about consumers being able to switch to environmentally friendlier options *within* their preferred class, as was found to be the case in Ireland (Rogan et al 2011).

Table 6: Total tax bill for each policy

Scenario	Mean	Std. Dev.	Min	Max
	Less than 160 g/km			
Actual	786.01	967.23	376.25	5506.49
Policy A	280.28	31.44	199.08	319.20
Policy B	336.34	37.72	238.90	383.04
Policy C	420.42	47.15	298.62	478.80
	160-180 g/km			
Actual	1976.77	2500.78	585.50	12964.80
Policy A	1192.36	38.17	1128.12	1247.54
Policy B	1039.06	33.27	983.08	1087.14
Policy C	1192.36	38.17	1128.12	1247.54
	180-220 g/km			
Actual	5303.92	3768.57	636.11	19767.61
Policy A	7404.80	400.26	6844.56	8288.56
Policy B	8184.26	442.40	7565.04	9161.04
Policy C	8379.12	452.93	7745.16	9379.16
	220-300 g/km			
Actual	17357.90	8955.89	928.44	38804.61
Policy A	21258.01	1672.92	18734.85	23740.50
Policy B	21508.10	1692.60	18955.26	24019.80
Policy C	21258.01	1672.92	18734.85	23740.50
	More than 300 g/km			
Actual	28874.51	8512.20	17270.40	38804.61
Policy A	31455.82	6349.03	27089.10	44366.40
Policy B	31455.82	6349.03	27089.10	44366.40
Policy C	52426.36	10581.72	45148.50	73944.00

Figure 3: Impact of emissions tax on the distribution of new vehicle sales

CO_2 emissions class

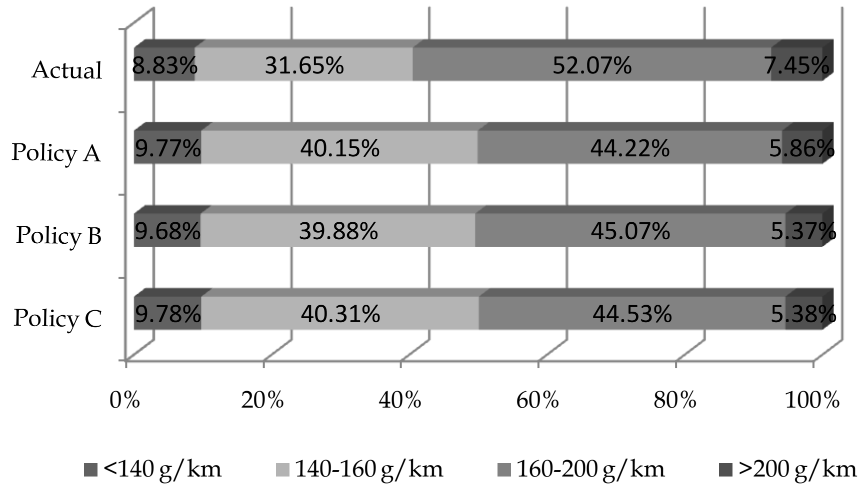

Figure 4: Impact of emissions tax on the distribution of new vehicle sales by

by vehicle class

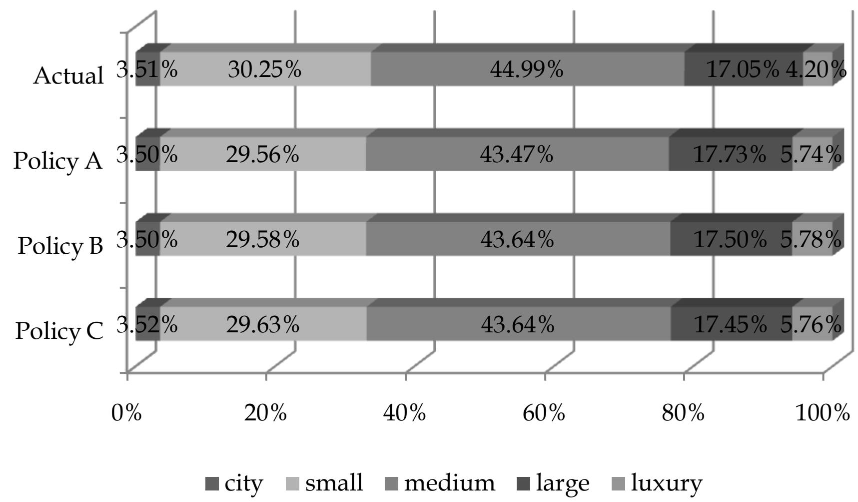

Table 7 summarizes the changes in public revenue, consumer welfare, environmental benefit and profits. All three policies are approximately revenue-neutral, as intended. They all achieve a reduction in CO_2 emissions while also improving both consumer welfare and profits. The reduction in CO_2 is smaller than what is achieved with the feebates considered earlier. This is because the substitution of the consumption tax with the emissions tax raises overall sales, while the feebate schemes lower overall sales. The improvement in consumer welfare and profits is likely due to the fact that the emissions taxes we considered are less distortionary than the existing consumption tax. With further experimentation one should be able to design schemes that achieve greater reduction in emissions while at the same time not adversely affecting consumers and producers.

Table 7: Simulated impact of an emissions-based tax

	Change in:				
Policy	Public revenues[1]	Consumer welfare[1]	Profits[1]	CO_2 emissions[2]	Total welfare[1] (SCC[3] = 15)
A	0.7	0.7	5.1	-324	6.5
B	-0.6	0.6	5.2	-579	5.2
C	0	0.2	5.1	-1,171	5.3

Notes: [1] Expressed in million euros; [2] Expressed in tonnes; [3] SSC refers to Social Cost of Carbon in euro/tone.

5. CONCLUSION

We present a simulation analysis of the effects of introducing emissions-based taxation of automobiles in Cyprus. Simulations were based on a nested logit demand system that was estimated using data from the Cyprus automobile market for the period 2006-2008. Two broad policy options were considered. The first one introduces a feebate on top of existing taxes. The second one completely replaces the existing consumption tax with an emissions-based tax that is designed to raise the same amount of revenue.

Introducing a feebate will reduce emissions, mostly by inducing a shift from high-CO_2 to low-CO_2 vehicles in the same class. Revenue neutrality can be achieved by picking a pivot point in the 120-140 range. Consumer and producer welfare will decrease for all feebate schemes we considered. Using typical estimates for the social cost of carbon, we find that the benefit from emissions reduction is not substantial enough to outweigh consumer and producer loss due to the feebate.

Our second policy replaces the existing consumption tax with an emissions tax in a revenue-neutral manner. The new tax has to be nonlinear in order for revenue neutrality to be possible. All three tax schemes we considered increase consumer and producer welfare and decrease emissions, but the reduction in emissions is quite small relative to the feebate. This is because the emissions tax leads to an increase in sales while sales decrease under the feebate. The upside is that - if revenue neutrality is not required - it should be possible to design schemes that decrease emissions more substantively while at the same time increasing revenues and consumer and producer welfare.

There are several caveats to the analysis. One is that it has a short-term outlook. It examines the impact of a policy change in the first year that it is implemented, focusing on consumer response and keeping the supply side fixed. In the longer term importers might respond to this policy by importing more fuel efficient vehicles. If this is the case, then our estimates will understate the policy's true impact. It should also be noted that the impact of feebate-like schemes takes many years to materialize because they exclusively target new cars. Emissions of new cars will decrease because of the policy but emissions of the existing car stock will remain the same. It will take several years (the average life of a vehicle) for the entire car stock is replaced with vehicles with lower emissions. This is an important disadvantage of feebate schemes relative to gasoline taxation. The latter has a greater immediate impact because it is levied on the entire car stock. Another caveat is that used vehicles were not included in the demand system because of lack of data. Hence, our model does not capture any substitution from new vehicles to used vehicles due to the introduction of a new tax scheme. Finally, it is always possible to estimate more general models that generate richer substitution patterns.

Caveats aside, the analysis is a useful exercise because it highlights and quantifies the tradeoffs involved in the design of an appropriate emissions-based taxation scheme for new automobiles. It shows how one can carefully design a tax/feebate scheme that can achieve the policy objective of emissions reduction at a minimal cost to society's welfare.

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APPENDIX

Demand estimates

Table 8 reports estimates of the nested logit demand system. The 1-level NML estimates are from a one-level nested logit with size classes (determined primarily by engine capacity). The 2-level NML estimates are from a two-level nested logit with size classes as the first group and fuel type (diesel or gasoline) as the second group. Estimation closely followed Adamou, Clerides and Zachariadis (2012a); we refer interested readers to that paper for the details.

Table 8: Nested logit estimates

Variables	1-level NML		2-level NML	
	OLS	IV	OLS	IV
Price	-0.0450***	-0.0732***	-0.0459***	-0.0779***
	(0.0029)	(0.0065)	(0.003)	(0.0070
ln(sj/g)	0.8130***	0.7226***		
	(0.0202)	(0.1884)		
ln(sj/h)			0.8256***	0.7460***
			(0.021)	(0.1419)
ln(sh/g)			0.7635***	0.5772***
			(0.0323)	(0.1342)
Consumption	-0.0027	0.0248	0.0241	0.1002**
	(0.0245)	(0.0293)	(0.028)	(0.0462)
Automatic Gearbox	-0.0761	0.0632	-0.0747	0.0832
	(0.0607)	(0.1404)	(0.0606)	(0.113)
Maximun Speed	0.0093***	0.0118***	0.0096***	0.0128***
	(0.0016)	(0.0018)	(0.0016)	(0.002)
Horsepower^2	0.00933***	0.00005***	0.00001**	0.00005***
	(0.00159)	(0.00001)	(0.00001)	(0.00001)
Length	0.0006***	0.0009***	0.0006***	0.0008***
	(0.0001)	(0.0001)	(0.0001)	(0.0001)
Japanese	0.1903**	0.2194*	0.1904**	0.2216**
	(0.0803)	(0.1231)	(0.0801)	(0.1094)
Europoean	0.2692***	0.3582***	0.2768***	0.3841***
	(0.0738)	(0.087)	(0.0736)	(0.0873)

(Continued)				
Constant	1.6075***	-1.3011	-8.5637***	-10.5250***
	(0.4987)	(2.9522)	(0.387)	(0.6497)
F-test	224.43***	39.66***	203.65***	39.12***
Underidentification test		7.124***		13.975***
Overidentification test		0.132		2.53
H_0: $\sigma_1 = \sigma_2$				4.27**

Notes: Significance levels: ***: 1%, **: 5%, *: 10%. Standard errors are in parentheses.

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