Optimal Emission Charges and the Differential Taxation of Leaded Gasoline

Fernando Navajas

1. Introduction

The reduction of lead in gasoline, both in response to the health effects of lead and to the introduction of air pollution control technologies such as catalytic converters, is today regarded as a policy spreading worldwide[1]. Some industrialized nations such as the U.S., have already completed the transition to unleaded gasoline while others -some european countries- are moving behind. Although the picture is not homogeneous for developing countries, the general trend is quite clear insofar as this substitution is concerned. Argentina, for example, has started that transition making unleaded gasoline available in most gas stations. At the same time a legislative project is being under parlamentary discussion (already approved by one of the chambers) to establish a deadline for a complete move towards unleaded gasoline as well as the lead content of available gasolines throughout the transition[2]. In instrumental terms, the projected law relies on a comand-and-control approach without referring to benefits and costs nor to the use of economic incentives to manage the phasedown of lead.

This paper does not take sides about the velocity of the lead phasedown in Argentina nor about the (benefit-cost or cost effective oriented) policy design for its accomplishment. Rather, our motivation is to explore conditions for the use of emission charges in a general framework of optimal indirect taxation in order to guide pricing policies during the transition. Instead of seeing taxes as the only, or even the main, instrument to guide such a transition program, we alert on the consequences of neglecting taxes and thus giving wrong signals to consumers and

---

[1] See for instance, Faiz et.al. (1992, ch. 9).

[2] The content of lead in gasoline used to be in Argentina around 0.40 gplg (grams per leaded gallon); the european standard is 0,15 gplg and "unleaded" is considered when the contents drops to 0.026 gplg. The argentine legislation projects a transition throughout these values.

producers while at the same time attempting to imposse a chronogram for substitution[3]. In this vein, we attempt to contribute to the design of emission charges although we do not, at this stage, make progress towards computational aspects.

The structure of the paper is the following. In section 2 we describe the analytical framework with reference to existing literature on the topic. Section 3 derives optimal indirect tax formulae in the presence of externalities. Section 4 reassess the issue with a direction-of-tax-reform approach, establishing conditions for the desirability of an emission charge on leaded gasoline. The introduction of the concept of the distributional (or social) characteristic of lead motivates Section, 5 which reconsiders the way the distributional impact of an environmental policy should be interpreted. In Section 6 it is shown an explicit solution to the differential tax on leaded gasoline assuming a symmetric response of the demand for both types of gasoline to cross-price changes. Finally Section 7 summarizes the main findings and suggests how the research can be extended.

2. Basic Analytical Framework

We frame the discussion within an optimal indirect taxation framework allowing for the presence of an externality (eg. Sandmo, 1975). The specific formulation of the model is adapted to the purposes of the paper in order to fucuse on the differential taxation of leaded vs. unleaded gasoline.

We assume H consumers indexed by $h=1,...H$ who can buy three commodities: an

[3] The most comprehensive benefit-cost analysis on the reduction of lead in gasoline, conducted by Scharwtz et.al. (1985) in the U.S. Environmental Protection Agency, discussed explicitly the introduction of a pollution charge on gasoline based on its lead content (pp. 1-21/22, op.cit) but concluded that even though atractive, due its flexibility, the effect of a pollution charge will not be, in practice, materially different from a quantity standard. The other reason was institutional, in the sense that the Agency may not have statutory authority to levy such a charge and that legislative debates would cause significant delays.

aggregate good, x_o^h , and leaded x_L^h or unleaded gasoline, x_u^h . The problem of consumer h is to choose $\underline{x}^h = (x_o^h, x_L^h, x_u^h)$ to maximize his (cuasi-concave) utility function

$$U^h = U^h\ (x_o^h, x_L^h, x_u^h, X_L^{-h}) \tag{1}$$

subject to his budget constraint $\sum_i q_i \cdot x_i^h \le Y^h,\ \ i = O, L, U$; where Y^h is income, $q_i = p_i + t_i$ are consumer prices (defined as producer prices p_i plus taxes t_i), and $X_L^{-h} = (x_L^1 + \ldots + x_L^{h-1} + x_L^{h+1} + \ldots + x_L^H)$ is the sum of leaded gasoline consumed by all agents except h . This formulation is consistent with previous analysis (Sandmo, 1975) and amounts to assuming either that the negative externality that h faces does not depend on his own consumption, or that he ignores his own contribution to the aggregate. This seems a fair assumption for the case studied, in the sense that h 's damage relates to the total amount of leaded gasoline but not to his own consumption. For the analysis undertaken in the next sections we also assume that the externality is "separable" in the sense that it does affect utility but not demands for other goods (see Diamond, 1973).

The main advantage of this specification of the "externality problem" is its simplicity, and the existence of well known results on the structure of indirect taxes. However, one should recognize some implicit assumptions in so far as the environmental damage of lead is concerned. First, we are ignoring the flow-stock dimension, so pervasive in polution problems; the exclusive dependence on the flow of leaded gasoline assumes a rather short persistence of lead in the environment[4]. Second, we also ignore other sources of lead emissions and the corrective taxation of the related goods; however, establishing a priority on lead in gasoline has been the line recommended by researchers and policy makers in the area, although other sources are usually recognized as relevant (CDC, 1991b; ch.3). Finally, we do not model consumer

---

[4] The literature on lead in gasoline suggests that this assumption would not be too restrictive. See Schwartz et.al. (1985, pp. II - 2 and III - 23) where although it is conceded that it is very difficult to model individual exposure pathways to lead, the relatively contemporary statistical association between lead in blood and gasoline lead would suggest that stock or persistence effects are not so important.

decisions considering explicitly that lead damage is concentrated on health effects on young children or on adults with specific characteristics (i.e. suffering high blood pressure)[5].

From the production side we follow the typical formulation that assumes a constant returns to scale technology in a competitive industry. Firms produce X_o or gasoline (leaded X_L or unleaded X_U)[6]; profits are assumed to be nil in equilibrium and demand equals supply in all markets. It is assumed that all gasoline is demanded as a final good and that there are no production externalities.

Finally, the government budget constraint is writen as $\sum_i t_i \cdot X_i = R$ where R is the (assumed fixed) financial requirement. We do not model the expenditure side of the government; in particular, it is assumed that there are no public expenditures directed at alleviating the externality; this is a relevant assumption for the argentine case.

3. Optimal Indirect Taxes and Emission Charges on Leaded Gasoline

Given the previous framework one can study the structure of indirect taxation in a multi-objective setting. That is, in a second-best fashion, the government has to select indirect taxes on three goods so as to balance efficiency-financing-distributional objetives as well as to correct for externalities. This results from solving the problem

$$\underset{t}{Max}\ W\,(V^h = U^h[x_o^h(\underline{q}, Y^h), x_L^h(\underline{q}, Y^h), x_U^h(\underline{q}, Y^h), X_L^{-h}(\underline{q}, Y)]) \tag{2}$$

$$\text{subject to } \sum_i t_i \cdot X_i(\underline{q}, Y) = R$$

---

[5] Cf. Schwartz et.al. (1985, Ch. 5) and CDC (1991 a).

[6] Aggregate profits are $\Pi = \sum_i p_i \cdot X_i - F(\underline{X})$ where $F(\underline{X})$ are economy-wide labour requirements for all goods $(i = O, L, U)$.

where $W[V^h(.)]$ is the social welfare function, depending on indirect utilities $V^h(.)$ of the h agents, which in turn are maximum-value functions resulting from the solution of the consumer problem; that is, substituting marshallian demands $x_i^h\ (q, Y^h)$ into direct utilities[7]. First order conditions to this problem are (interior solutions)

$$\sum_h \left(\frac{\partial W}{\partial V^h}\right)\left(\frac{\partial V^h}{\partial t_i}\right) + \lambda\ [X_i + \sum_k t_k \left(\frac{\partial X_k}{\partial t_i}\right)] = 0 \qquad (3)$$

$$i, k = O, L, U$$

where λ is the lagrangean multiplier associated with the government budget constraint, normally interpreted as the social marginal cost of raising funds (through distortionary taxation) for the public sector. For simplicity we further assume independence between gasoline (both leaded and unleaded) and other goods (X_o) . Solving the system (3) for $\hat{t}_i = \frac{t_i}{q_i}$ (i.e. marginal departures from first-best, marginal-cost prices) we have

$$\hat{t}_O = \frac{(\lambda - D_O)}{\lambda}\ \frac{1}{\eta_{OO}} \qquad (4)$$

$$\hat{t}_L = \frac{(\lambda - D_L)}{\lambda}\ \frac{\eta_{UU}}{\Delta} + \frac{(\lambda - D_U)}{\lambda}\ \frac{\eta_{UL}}{\Delta}\ \left(\frac{s_U}{s_L}\right) + \frac{E_L}{\lambda} \qquad (5)$$

$$\hat{t}_U = \frac{(\lambda - D_U)}{\lambda}\ \frac{\eta_{LL}}{\Delta} + \frac{(\lambda - D_L)}{\lambda}\ \frac{\eta_{LU}}{\Delta}\ \left(\frac{s_L}{s_U}\right) \qquad (6)$$

where:

$D_i = \sum_h \beta^h . \frac{x_i^h}{X_i}$ is the distributional characteristic of good $i = O, L, U$ [8].

$\beta^h = (\partial W / \partial V^h)(\partial V^h / \partial Y^h)$ is the social marginal utility of income for consumer h .

---

[7] Problem (2) subsumes optimal decisions by consumers and firms and assumes market clearing conditions. It thus characterize a second-best efficient allocation in a competitive economy.

[8] Defined as the weighted sum of the share of consumer h in the total consumption of commodity i , with weights given by the social marginal utility of income of h .

$\eta_{i,j} = \frac{\partial X_i}{\partial q_j} \cdot \frac{q_j}{X_i}$ is the elasticity of total demand i with respect to price j ($i,j = O,L,U$; defined with a negative sign when $i = j$).

$\Delta = \eta_{LL}\,\eta_{UU} - \eta_{LU}\,\eta_{UL}$

$s_i \,/\, s_j = q_i\,X_i \,/\, q_i\,X_j$ is the expenditure on good i relative to that on j ; $(i,j = L,U)$.

Finally,

$$E_L = -\sum_h \left(\frac{\partial W}{\partial V^h}\right) \left(\frac{\partial V^h/\partial X_L^{-h}}{q_L}\right) = -\sum_h \beta^h \,\frac{(\partial V^h \,/\, \partial X_L^{-h})}{\partial U^h \,/\, \partial x_L^h}$$

is the weighted sum of the disutility of lead in terms of leaded gasoline, the weights given by the β^h . In conceptual terms E_L comes close to what could be termed the distributional or social characteristic of lead; we later elaborate a bit more on this parameter.

Solutions (4) to (6), although not of a closed-form nature, are tax-formulae of an optimal indirect tax problem in the presence of externalities (Cf. Sandmo, 1975). The well known result, i.e. that the introduction of external effects give rise only to an additive term to the tax formula of the good causating the externality, is shown in expression (5): others things equal, the tax on leaded gasoline should be raised to correct for the environmental damage of lead. The resulting departure of the consumer price of lead from marginal cost is a sort of "Ramsey-Boiteux-Feldstein-Pigou pricing". Leaving appart its label, the basic general point is that "green" taxes are, at least conceptually, easily accomodated in an optimal structure of indirect taxes (Cf. Sandmo, 1975).

The trouble with solutions (4) - (6) is the well known lack of information on demand elasticities and other parameters that are endogenous. Further, one cannot easily suggest a positive (with respet to unleaded) differential tax on leaded gasoline since demand elasticities and distributional characteristic may induce opposite effects. In fact, under usual assumptions about the social welfare function, leaded gasoline has a higher "distributional characteristic" than unleaded one (since it is most consumed by people with older cars); this has to be confronted with other effects (such as the "distributional or social characteristic of lead"). In the next section we address the issue following a direction-of-tax-reform approach.

4. Welfare Improving Tax Adjustments of Leaded/Unleaded Gasoline

It is most likely that any evaluation of differential taxes on leaded/unleaded gasoline will proceed from a situation "outside" the second-best allocation characterized in the last section; in fact, any study or proposal of changes will possibly start with rather uniform taxes, between both types of gasoline.

The tax reform analysis (Guesnerie 1977, Ahmad and Stern, 1984) is basically a welfare-improving exercise that looks at the direction of marginal adjustments in the structure of indirect taxes form "outside" the welfare maximum. The approach is very informative in the sense that it looks at the so called marginal cost, in terms of social welfare, of raising money through different goods: if they are different then there is evidence that the tax structure has to be adjusted (reducing taxes where this cost is high relative to others, and viceversa). In some cases such as uniform taxes -and provided that these are not optimal (Deaton and Stern, 1986; Stern 1990)- there exist a simple representation for any two goods in terms of their distributional characteristics.

We reformulate this argument for the present case and show that the marginal cost -in welfare terms- of raising funds through a tax on leaded gasoline includes the environmental damage caused by lead. Moreover, the ratio between these marginal costs for leaded and unleaded gasoline is shown to depend -under some assumptions about demand elasticities - on the distributional characteristic of leaded and unleaded gasoline as well as on that of lead. The introduction of an emission charge is then easily interpreted as a direction of tax reform problem.

From the first order conditions of the optimal tax problem (3) it results a proportionality between the welfare impact $\partial W / \partial t$ and the revenue impact $\partial R / \partial t$ of a change in taxes such that

$$-\frac{\partial W / \partial t_i}{\partial R / \partial t_i} = \lambda \qquad i = O, L, U \tag{7}$$

where λ is the lagrangean multiplier standing for the social marginal cost of raising public funds. In expression (7) all margins are exploited in the sense that this marginal cost is the same for all goods; if this is the case no welfare improvements are possible given that the maximum has been attained. On the other hand, the marginal tax reform approach studies those cases outside this optimum, where the marginal cost of raising an extra unit of money on the good i ; $\lambda_i = -(\partial W / \partial t_i) / (\partial R / \partial t_i)$ is different from that on the good j (λ_j) .

From (2) and (3) we can write $(i, k = O, L, U)$

$$\lambda_i = \frac{\sum_h \beta^h \cdot x_i^h - \sum_h \frac{\partial W}{\partial V^h} \cdot \frac{\partial V^h}{\partial x_L^{-h}} \cdot \frac{\partial x_L^{-h}}{\partial t_i}}{X_i + \sum_k t_k \cdot \frac{\partial X_k}{\partial t_i}} \tag{8}$$

Dividing both numerator and denominator by X_i , assuming that taxes are uniform, using the adding-up property of demands[9] and arranging terms, it can be shown that $i = O, L, U$

$$\lambda_i = [D_i - E_L \cdot \eta_{L,i} \cdot (\frac{s_L}{s_i})] / (1 - a) \tag{9}$$

where $0 < a < 1$ is the proportional factor between taxes and consumer prices,

---

[9] Once divided by X_i , and using $t_i = a \cdot q_i$, the denominator of (8) becomes

$$1 + \frac{1}{X_i} \sum_k t_k \cdot \frac{\partial X_k}{\partial t_i} = 1 + \frac{a}{X_i} \sum_k q_k \cdot \frac{\partial X_k}{\partial t_i} = 1 - a$$

since $\sum_k q_k \cdot \frac{\partial X_k}{\partial t_i} = -X_i$ by the adding up property of demands.

i.e. $t_i = a \cdot q_i$.

In words, the marginal social cost of raising funds through good i is proportional to its distributional characteristic (D_i) [10] corrected by a term which depends on the distributional (or social) characteristic of lead times the price elasticity $\eta_{L,i} = (\partial X_L / \partial t_i) \cdot (t_i / X_L)$, defined with a minus sign when $i = L$, and the relative expenditure shares $s_L / s_i = q_L \cdot X_L / q_i \cdot X_i$.

This result tends to depart from the conclusions derived in the literature on optimal tax rules in the presence of externalities: we need to consider cross price effects between the good creating the externality and the rest of commodities[11]. Since outside the second-best solutions cross-price effects do not cancel (as it occurs in solutions (4) to (6)), one has to consider them in any evaluation of a marginal tax reform that will involve an environmental effect. Unless the second-best solutions are fully (directly) implemented, in principle one cannot ignore taxes on substitutes/complements to the externality-creating commodity. The remaining of this section focuses on the direction of reform of taxes on leaded/unleaded gasoline.

From expression (8) we can write the ratio between λ_L / λ_U as

$$\frac{\lambda_L}{\lambda_U} = \frac{D_L - E_L \cdot \eta_{LL}}{D_U + E_L \cdot \eta_{LU} (s_L / s_u)} \tag{10}$$

If this ratio is less than one, then an increase in the tax on leaded gasoline <u>relative</u> to that on unleaded will be a "welfare-improving" reform. Unlike the traditional case addressed in optimal

---

[10] Whithout externalities in the consumption of X_L, λ_i is proportional to D_i , as in the simple model of tax reform (Ahmad and Stern, 1984).

[11] In Sandmo's (1975) words: "the fact that a commodity involves a negative externality is not in itself an argument for taxing other commodities which are complementarity with it, nor for subsidizing substitutes" (p.92). This can be clearly observed in solutions given in expressions (4) to (6)

tax reform models without externalities, where $\lambda_i / \lambda_j = D_i / D_j$, expression (10) shows that the ratio "directing" the reform will depend on E_L as well as on the elasticities η_{LL}, η_{LU} and relative shares (s_L / s_U). The next result states conditions for the ratio λ_L / λ_U to be less than one.

Proposition 1: Suppose that (i) taxes are uniform; (ii) the demand for other goods (X_o) is independent of gasoline prices and (iii) identical cross-price elasticities for leaded and unleaded gasoline (i.e. $\eta_{LU} = \eta_{UL}$). Then a necessary and sufficient condition for an emission charge on leaded gasoline to be welfare-improving (i.e. $\lambda_L / \lambda_U < 1$) is that

$$E_L > \frac{D_L - D_U}{\Delta} \tag{11}$$

where $\Delta = 1 + \eta_{LU}(2 + \frac{(s_U - s_L)^2}{s_U \, s_L})$

Proof: Using the (aggregate) consumers budget constraint $q_o \cdot X_o + q_L \cdot X_L + q_U \cdot X_U = Y$, differentiating w.r.t. q_L, forming elasticities and using assumption (ii) we have

$$s_L \,(1 - \eta_{LL}) + s_U \cdot \eta_{UL} = 0$$

Using assumption (iii) we have

$$\eta_{LL} = 1 + \eta_{LU} \,(s_U / s_L)$$

We now proceed by working on the difference $\lambda_L - \lambda_U$ which is required to be negative. Substituting the value for η_{LL} in λ_L we can write

$$\lambda_L - \lambda_U = \frac{1}{(1-a)} \,[D_L - D_U - E_L \,(1 + \eta_{LU}\frac{s_U}{s_L} + \eta_{LU} \,\frac{s_L}{s_U})] \tag{12}$$

where it can be shown, by algebraic manipulation that

$$1 + \eta_{LU} \frac{s_U}{s_L} + \eta_{LU} \frac{s_L}{s_U} = 1 + \eta_{LU} \left(2 + \frac{(s_U - s_L)^2}{s_U\, s_L}\right)$$

This term is, in turn, equal to $\Delta = \eta_{LL}\,\eta_{UU} - \eta_{LU}\,\eta_{UL}$ whenever assumption (iii) (that is $\eta_{LU} = \eta_{UL}$) holds (see proposition 2 for a proof of this). From (12) we easily arrive at condition (11).

This result helps to limit the range of "indeterminancy" about the desirability of a tax movement based on an emission charge unleaded gasoline when it is argue that tax will hurt low-income consumers (relative to those consuming unleaded gasoline). Proposition 1 states that if leaded gasoline has a higher distributional characteristic than unleaded one (as it is likely to be case) then the distributional characteristic of lead (that reflects the environmental damage) has to bridge the gap between D_L and D_U to justify the introduction of an emission charge. For low values of the cross-price elasticity η_{LU} the difference between these two parameters is almost enough to determine the desirability of a tax change. The next corollary illustrate the case without distributional objectives.

<u>Corollary 1</u>: In the absence of distributional objectives (i.e. $\beta^h = 1$ for all h), condition (10) becomes (since $D_L = D_U = 1$)

$$E_L = -\sum_h \frac{\partial V^h / \partial X_L}{\partial U^h / \partial x_L^h} > 0 \tag{13}$$

that is, it is enough to recognize a negative externality in the consumption of leaded gasoline.

Expression (13) is also a valid condition for an introduction of an emission charge on leaded gasoline when the distributional characteristic of leaded and unleaded gasoline are the same[12].

5. The Distributional Impact of Environmental Policy Reconsidered

The direction-of-tax reform approach, when referred to the case of uniform taxes as a starting point, has the advantage of calling attention to the role of distributional characteristics whenever distributional objectives are introduced into the analysis. In Navajas and Porto (1994) a distinction is made between the appropiate parameter to evaluate the distributional impact of a tax and the usual practice of following the traditional distributive-incidence approach which, instead, focuses on the share of the good (to be taxed) in the budget of different income groups. There, it is maintained that this last way of addressing a distributional impact of a tax, overlooks the rol of the distributional characteristic as an adequate parameter (stressed by the optimal tax literature) to evaluate such an impact. Using a direction of tax reform argument it is shown that relying on budget shares may incorrectly exaggerate the distributional impact of some taxes and misguide tax changes.

This explicit distinction is also missing in current discussions of the distributional impact of environmental policies (e.g. Cropper and Oates, pp. 727) which rely on traditional distributional incidence meassures of benefits and costs of environmental policies. They rightly recognize, on the one hand, the difficulties in assessing beneficiaries of environmental policies (classified by income) and, on the other, the likely impact of these policies on consumer prices and on the budget of low income households. However, the concept of distributional characteristic is neither considered in the studies quoted nor taken as a conceptual tool. This parameter is clearly a useful byproduct of the optimal tax literature to which pigouvian taxation belongs.

---

[12] One can imagine, however, other possible cases; for instance a strong separation between consumers of leaded gasoline, consumers of unleaded gasoline and individuals hurt by lead (who might not even consume gasoline at all).

Condition (11) can be interpreted as a distributional benefit-cost comparisson of an environmental policy based on a tax/emission charge on leaded gasoline. Benefits are approximated by the distributional or social characteristic of lead, while costs are proportional to the distributional characteristic of leaded gasoline net of that of unleaded gasoline. It is still true the observation that benefits (E_L) are much more difficult to estimate than costs $\frac{(D_L - D_U)}{\Delta}$; however both meassures rely on the concept of distributional characteristic, not on incidence indicators.

Unlike D_L and D_U which can be computed directly from data in household expenditure surveys[13], E_L needs a much richer and costly set of information to be estimated. For this purpose it is needed a rather thorough classification of the atributes or characteristics of individuals and groups affected by lead[14].

Even though the preliminar stage of this work does not allow to make progress on estimating parameters, we notice that the right hand side of condition (11) can be interpreted as a lower bound on E_L (if a tax/emission charge on leaded gasoline is to be recommended) that should not be difficult to estimate for policy purposses.

6. Tax Formulae and Differential Taxation of Leaded/Unleaded Gasoline: The Symmetric Case

Section 4 presented results (proposition 1) which allows, under certain conditions, making

[13] Unfortunately, available surveys for Argentina (e.g. INDEC, 1988) preceded the introduction of unleaded gasoline. One possible, rough approximation would be to use expenditure data of regular and premium gasoline by income group.

[14] Data as rich as the National Health and Nutrition Examination Survey (NHANES II) reported by Schwartz et.al. (1985, pp. III-4) would allow a fairly good start.

statements on the direction of tax (emission charge) reform with fewer parameters than those required to compute optimal indirect tax formulae (4) to (6). A critical view of the results would possibly be to qualify its usefulness for the actual design of tax/emission charges. That is, the question of how much higher the tax on leaded gasoline should be (if this is the case) cannot be adequately answered by this route. Instead we are forced to look at the optimal tax formulae (4) - (6) and these require much more information than distributional characteristics.

In this section we shown that when cross-price effects between leaded and unleaded gasoline are the same then even formulae (5) and (6) are relatively easier to approximate. The basic assumptions are very similar to those used in proposition 1 (except that uniformity is no longer required). It turns out that the form of the differential tax on leaded gasoline is very simple and resembles the result stated in proposition 1.

Proposition 2: Take conditions (5) and (6) for $\hat{t}_L$ and $\hat{t}_U$, and suppose the symmetric case where cross-price effects between (demand for) leaded and unleaded gasoline are identical, i.e. $\eta_{LU} = \eta_{UL}$. Then, the differential optimal tax on leaded gasoline is:

$$\hat{t}_L - \hat{t}_U = \frac{\hat{D}_U - \hat{D}_L}{\Delta} + \hat{E}_L \tag{14}$$

where $\hat{D}_i = D_i / \lambda \quad , \quad \hat{E}_L = E_L / \lambda$ (15)

and $\Delta = 1 + \eta_{LU} \left[2 + \frac{(s_L - s_U)^2}{s_L \cdot s_U}\right]$ (16)

Proof: We proceed by first showing that when $\eta_{LU} = \eta_{UL}$ then Δ becomes expression (16). First, using the aggregate consumers budget constraint, differentiating w.r.t. q_L and q_U, and forming elasticities, we sustitute for η_{LL} and η_{UU}:

$$\Delta = \eta_{LL} \cdot \eta_{UU} - \eta_{LU} \cdot \eta_{UL} = (1 + \eta_{UL} \frac{s_U}{s_L}) \; (1 + \eta_{LU} \cdot \frac{s_L}{s_U}) - \eta_{LU} \cdot \eta_{UL} \cdot$$

Assuming $\eta_{LU} = \eta_{UL}$ and manipulating this expression we arrive at expression (16).

Defining $\hat{D}_i = D_i \,/\, \lambda$ and $\hat{E}_L = E_L \,/\, \lambda$ we can write (5) and (6) as

$$\hat{\varepsilon}_L = (1 - \hat{D}_L) \frac{\eta_{UU}}{\Delta} + (1 - \hat{D}_U) \frac{\eta_{UL}}{\Delta} \frac{s_U}{s_L} + \hat{E}_L$$

$$\hat{\varepsilon}_U = (1 - \hat{D}_U) \frac{\eta_{LL}}{\Delta} + (1 - \hat{D}_L) \frac{\eta_{LU}}{\Delta} \frac{s_L}{s_U}$$

Subtracting $\hat{\varepsilon}_U$ from $\hat{\varepsilon}_L$ and using $\eta_{UU} = 1 + \eta_{LU} \frac{s_L}{s_U}$ and

$\eta_{LL} = 1 + \eta_{UL} \frac{s_U}{s_L}$, we arrive at expression (14).

The difference between $\hat{\varepsilon}_L$ and $\hat{\varepsilon}_U$ is therefore approximated by parameters on the R.H.S. of expression (14). The next two corollaries of proposition 2 are useful both for illustrative and computational purposes.

<u>Corollary 2.1</u>: If cross-price effects between leaded and unleaded gasoline are both equal to zero, i.e. $\eta_{LU} = \eta_{UL} = 0$ then the differential tax on leaded gasoline depends exclusively on distributional characteristics. On the other hand as $\eta_{LU} = \eta_{UL}$ tends to $-\infty$; then $(\hat{\varepsilon}_L - \hat{\varepsilon}_U)$ tends to $\hat{E}_L$.

<u>Corollary 2.2</u>: If the optimal or "policy-targeted" allocation is such that leaded gasoline is substituted away, i.e. s_L tends to 0 , then the differential tax on leaded gasoline depends exclusively on distributional characteristics. The same happens if the substitution is minimal; i.e. s_U tends to 0 .

Proof: In both cases $\Delta = 1$ since, using L'Hopital's rule,

$$\lim_{s_L \to 0} \frac{(s_L - s_U)^2}{s_L \cdot s_U} = \lim_{s_U \to 0} \frac{(s_L - s_U)^2}{s_L \cdot s_U} = -2 .$$

7. Final Comments and Further Research

Although preliminary, this work has attempted to shed light on the conditions for a desirable introduction and design of emission charges on leaded gasoline. As stated in the introduction we see this instrument as complement to others; but certainly one should avoid neglecting too much the role of prices and taxes for a succesful transition to the consumption of alternative fuels.

The main results can be summarized as follows. First, the introduction of an emission charge on leaded gasoline can be usefully stated as a direction-of-tax-reform problem. In such a case, Sandmo's (1975) remark that one should neglect (at least looking at the optimal formulae) cross-price effects between the good creating the externality and the rest, does not hold. However, under certain assumptions it is possible to characterize the marginal reform problem with a few parameters: an emission charge on leaded gasoline is welfare improving if the social damage of lead (defined as its distributional characteristic) is higher than an adjusted difference between the distributional characteristics of leaded and unleaded gasoline (Proposition 1). This way of looling at the problem helps at answering concerns about the distributional impact of a tax on the good creating a negative externality. If follows almost directly that one can give a different and complementary look at the question about the distributional impact of environmental policies, whenever they rely on taxes (Section 5).

Second, some progress can be made towards computing the optimal differential tax on leaded gasoline for the (symmetric) case where cross-price effects between both types of gasoline are identical. In such a case (stated as Proposition 2), one needs information about distributional characteristics relative to financial requirements $(\hat{D}_L, \hat{D}_U, \hat{E}_L)$, the cross-price elasticity η_{LU} $(=\eta_{UL})$ and the (equilibrium) expenditure shares (s_L, s_U) . However, the differential tax formula depends only on distributional characteristics (adjusted by λ) when consumers do not switch between leaded and unleaded gasoline or when the optimal allocation requires a complete move towards unleaded gasoline. The case where consumers react instantly to price differentials between both types of gasoline (i.e. $\eta_{LU} = \eta_{UL} \to -\infty$) implies a differential tax equal to the (adjusted) distributional characteristic of lead.

The reliance of results (both propositions 1 and 2) on the ability of consumers to switch between both types of gasoline seems to be not only instuitively correct but also very relevant to the case of leaded/unleaded gasoline. One view would be that switching costs are almost prohibitive, since people with old cars cannot use unleaded gasoline without avoiding maintenance costs, while people with new cars (with catalytic converters) cannot use leaded gasoline without seriously damaging their exhaustion-control equipment. According to this view the cross-price elasticities would be close to zero.

However, there is some evidence -at least for the argentine case- that this simple picture does not fit into actual behaviour. First, both types of consumers (old/new cars) can switch conciously to the "wrong" fuel if prices give them incentives to do so; that is why we stressed the role of taxation as an ingredient in a transition program to unleaded gasoline. These decisions are usually refered to, in the literature on the case, under the label of "misfuelling" problems. In particular, misfuelling by owners of new cars with catalytic converters imposes a cost to society which is higher than the individually perceived one. Second, for the argentine case all domestically produced new cars (since 1987) do not have catalytic converters and therefore their owners have no incentive to switch to unleaded gasoline if prices are the same for both fuels (as they are currently); therefore switching is feasible and can be induced by prices.

The introduction of misfueling decisions and their effect on consumers substitution between both types of gasoline seems one line in which the results of this paper can be extended allowing perhaps for asymmetric values of the elasticities η_{LU} and η_{UL} . Another useful extension would be to improve the supply side of the model to allow for the behaviour and incentives of producers to substitute away from leaded gasoline. Finally, any progress towards computing the optimal emission charge is a requirement for practical policy guidelines.

References

Ahmad, E. and N. Stern (1984) "The Theory of Reform and Indian Indirect Taxes", Journal of Public Economics, 25, pp. 259-98.

CDC (1991 a) Strategic Plan for the Elimination of Childhood lead Poisoning, Center for Disease Control, U.S. Department of Health and Human Services, Washington D.C. (February).

CDC (1991 b) Preventing Lead Poisoning in Young Children, A Statement by the Center for Disease Control, U.S. Department of Health and Human Services, Washington D.C., (October).

Cropper, M. and W. Oates (1992) "Environmental Economics: A Survey", Journal of Economic Literature, 30, pp. 675-740.

Deaton, A. and N. Stern (1986) "Optimally Uniform Commodity Taxes, Taste Differences and Lump-Sum Grants", Economics Letters, 20, pp. 263-66.

Diamond, P. (1973) "Consumption Externalities and Imperfect Corrective Pricing", Bell Journal of Economics, 4, pp. 526-38.

Faiz A., C. Weaver, K. Sinha, M. Walsh and J. Carbajo (1992) Air Pollution from Motor Vehicles, World Bank, Washington D.C., April.

Guesnerie, R. (1977) "On the Direction of Tax Reform", Journal of Public Economics, 7, pp. 179-202.

INDEC (1988) Encuesta de Gastos e Ingresos de los Hogares, Estudios 11, Buenos Aires.

Navajas, F. and A. Porto (1994) "Budget Shares, Distributional Characteristics and the Direction of Tax Reform", Economics Letters, 45, 4, August.

Sandmo, A. (1975) "Optimal Taxation in the Presence of Externalities", Swedish Journal of Economics, 77, pp. 86-98.

Schwartz J., A. Pitcher, R. Levin, B. Ostro and A. Nichols (1985), Cost and Benefits of Reducing Lead in Gasoline: Final Regulatory Impact Analysis, Report Nº 230-05-85-006 U.S. Environmental Protection Agency, Washington D.C., (February).

Stern, N. (1990) "Uniformity vs. Selectivity in Indirect Taxation", Economics and Politics, 2, pp. 83-108.