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Alinsato, Alastaire Sèna

University of Abomey-Calavi(Rep of Benin)

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An analytical framework toward the use of emission taxes: The Study case of Cotonou (Rep of Benin)[1]

Alastaire Sèna ALINSATO (alastaires@yahoo.fr):
University of Cocody-Abidjan and University of Abomey-Calavi/Benin

Abstract

As in numerous big cities in developing countries, environmental problems in Cotonou are becoming more and more severe. These problems are the result, among other factors, of the strong air pollution by the motorbike transport sector.

This study, while considering health expenditures due to air pollution, uses a general equilibrium model and an optimal model of taxation to derive the optimal level of the taxation that should be applied to the motorbike taxi. On the basis of simulations achieved from the derivative tax, the study shows that an instrument of control based on the polluter pay principle will help to reduce the emission of carbon monoxyde (CO).

Key world : Pollution – motorbike Taxi – Polluter Pay Principle – General Equilibrium Model – Optimal Tax

JEL Code : Q52, Q53, H21, D51

Introduction

As with many others developing African major cities, environmental problems in Cotonou are more and more noticeable. These problems are the result, among other things, of air pollution caused to a large extent by the transportation sector.

According to the World Bank (WB 2002), Benin's energy schedule shows that the transport sector is a high-energy consumer. It represents 62 percent of the country's oil expenses, four times more than the industrial sector. Moreover it has to be noted that transport mainly has a very local impact on air quality, in the absence of a reliable public transport system, air pollution has worsened because of an increasing number of old second hand cars (more than 240.000) and taxi-motorbikes (approxi. 80.000) (Fanou et al 2006). Gasoline is also of poor quality, due to illegal import of sub-standard products from neighboring Nigeria. This justifies why atmospheric pollution along Cotonou's major highways is almost all caused by transport. This was confirmed from results of various analyses: CO concentration level outside of the city was 10 times less than at the main intersections. (WB, 2002; Fanou et al, 2006)

Air pollution is associated with an increased risk of many adverse health effects; e.g. mortality, respiratory diseases and cancer (Fanou et al, 2006). The impact of air pollution on an individual's health from a vehicle's exhaust is determined by the increase in a large range of illnesses from respiratory and lead related illnesses to allergies and skin illnesses. A specific analysis of hospital

[1] Presented at the SEREG meeting (CEFRED)

data (survey carried out by the WB and *Clean Air Initiative in Sub-Saharan African Cities* in 2002) clearly indicates that air pollution in Cotonou is responsible for the high frequency of severe respiratory infections. Also, as concentrations of lead in the air are much higher than the norm (CO concentration reached 18mg/Nm3, almost double the norm), one can deduce that a certain number of neurological symptoms are developed mainly in children.

According to the WB (2002), emissions will double on average in 2010. The genotoxic compounds present in ambient air by the year 2010 will reach 8 times more than the norm in certain places and suspended particles from SO will become noticeable.

Given the evolution in the pollution level obtained from these calculations, the situation will obviously worsen and become unacceptable before 2010. It is therefore most important to take appropriate measures immediately to limit, as much as possible, the pollution of air quality in Cotonou.

The ABE (Agence Beninoise de l'Environnement) Benin Agency for Environment made a set of proposal for the purpose to reduce the air pollution in Cotonou: pollution stricter regulations for the quality of vehicles for sale in Cotonou, replacing 2 cycle motorbikes by 4 cycle motorbikes that pollute less especially in HC emission, modification of 2 cycle engines to reduce emissions, improvement of 2-cycle oil quality and of gas/oil mixtures, establishment of technical controls for 2-wheelers improvement in the carburant sector and establishment of trained mechanics. But face to the practical difficulties to apply those solutions, a tax based on the polluter pays principle is instituted in 2004 in the framework of the State budget in application of de framework law on environment (DSRP du Benin, 2005 or Poverty alleviation Program). This solution even more realistic has many problems with regards to it conception (this explains why since 2004 this tax has not been applied yet), in fact, unlike the other tax, pollution tax should be considered primarily for their environmental effects, not for their revenue potential. The purpose of my study is to propose an analytical framework toward the use of emission taxes in Cotonou (Benin).

1. Environmental management policies

There are five guiding principles for incorporating environmental concerns in to decision making. These principles can be used to design environmental instruments and to raise funds to finance environmental public investments plans in the sectoral and overall budget. They are, Polluter pays principle (PPP), user pays principle (UPP) (or resource pricing principle), precautionary principle (PP), subsidiary principle (SP), intergenerational equity principle (IEP)[2]. In the framework of this work we will emphasize the polluter pays principle

1.1 Polluter pays principle (PPP)

The Polluter Pays Principle was first widely discussed in the United Nations Conference on Environment and Development held in Rio de Janeiro of Brazil in June 1992. This principle was endorsed by all the attending representatives of the countries.
The PPP required that the polluter has to bear the cost of complying with environmental standards, which are predetermined by public authorities. If the polluters have to pay for the cost

[2] For the reader who are interested in those principles go to the link, http://www.dsd.gov.hk

of any pollution they cause, market forces will then encourage them to change their activities either by introducing new pollution control technologies or by switching to more efficient production process. In its original emergence the Polluter Pays Principle aims at determining how the costs of pollution prevention and control must be allocated: the polluter must pay. Its immediate goal is that of internalizing the environmental externalities of economic activities, so that the prices of goods and services fully reflect the costs of production. There are two objectives with PPP towards encouraging to more efficient production process, they are:

i. To promote economic efficiency in the implementation of pollution control policies.
ii. To minimize potential trade distortions arising from environmental policies. Bugge (1996))

PPP was partly based on equity considerations (the polluter should pay the cost of any mitigation measures), and partly ensure that countries do not provide competitive advantage for their producers by subsidizing the pollution abatement measures.

One more important point is that PPP is not necessary to achieve an efficient solution to an environmental problem and it does not require pollution to recede to zero levels, nor does it require reduction to optimal level even though it is not excluded. PP required only that the environment is in an acceptable state, which will evolve from a political process requiring inputs from local, national and international level.

The normative scope of the PPP has evolved over time to include also accidental pollution prevention, control and clean-up costs, in what is referred to as *extended Polluter Pays Principle*.

Today the Principle is a generally recognized principle of International Environmental Law, and it is a fundamental principle of environmental policy of both the Organization for Economic Co-operation and Development (OECD) and the European Community.

2. Polluter pays principle theoretical considerations

In order to present the most fundamental result in tax as a pollution control, we shall initially assume that efficiency - is the way to achieve a given target with the lowest cost- is the sole criterion used in deciding policy choice. Baumol and Oates (1971) showed that an efficient outcome could be achieved by setting a tax on emissions at the level where the Marginal Abatement Cost equals the Marginal Abatement Benefit. To state the theorem as Baumol and Oates put it: 'A tax rate set at level that achieves the desired reduction in the total emission of pollutant emission will satisfy the necessary conditions for the minimization of the program cost to the society'(Hanley et al,1997).

Formal proof of the efficiency properties of the a tax on emission have been provided by Baumol and Oates (1988) and by Fisher (1980). Based on an earlier model of Fisher (1980), Hanley et al (1997) showed that, by using a centralized model that the tax must be equal to the shadow price of pollution reduction in the problem of the social planner. This also implies that for a given tax level, the marginal abatement cost across all firms must be equal under the cost-minimizing solution. The discussion generally assumes uniformly mixed pollutant (the source and the spatial repartition don't matter).

Seekin et al (1983) examine the cost of meeting a target improvement in ambient levels of nitrogen dioxide (NO_2) in Chicago; given that NO_2 in a non-uniformly mixed pollutant, they verified that, the tax based instrument as stated by Fisher (1980) cannot achieve the least cost solution. We can then conclude that the assumption of uniformly mixed pollutant is important for the efficiency of the tax scheme.

Michaelis (1992), considers the problem of the multiples pollutants[3] from the point of view to how to design a tax system. The important question here is the level of efficient relative tax rates for the four main greenhouse gases (GHGs). He shows that the relative tax rate between two pollutants depend on their relative damage and dispersion coefficients. Michaelis shows that absolute tax rates depend on the initial stock of GHGs, the time period over which the model is run, the level of abatement costs and the initial period level of emission.

Pollution taxes have long been advocated by the environmental economists as an efficient means of controlling pollution. It was accepted by all governments of the OECD in 1972 and later in 1995 laid down in the Treaty of Rome. In February 2004, European Union governments and lawmakers reached agreement on this new legislation that will force industries guilty of polluting the environment to pay for the clean-up. The Agreement on New Directive on Environmental Liability with regard to the prevention and remedying of environmental damage will help to establish a common framework for applying the Polluter Pays Principle (PPP), one of the key environmental principles enshrined in the EU Treaty, to prevent environmental damage (caused or threatened by a range of occupational activities which present a risk to human health or the environment, or the manufacture, use, storage or transport of substances, products or goods which are already subject to regulation under relevant EU industrial, chemical and environmental legislation); and biodiversity damage (i.e. damage to protected habitats and species as defined under the Birds and Habitats Directive, or as provided for by National legislation) caused or threatened by any other occupational activities whenever the operator has been at fault or negligent. At the international level the Kyoto Protocol is an example of application of the PPP: parties that have obligations to reduce their greenhouse gas emissions must bear the costs of reducing (prevention and control) such polluting emissions.

From the above discussion it becomes clear that tax based instrument can lead to efficient control of pollution. However we cannot use directly the analytical framework of Fisher to design tax based environment control instrument especially in air pollution area since the pollutant is not uniformly mixed in Cotonou. Ideally we should seek for a model that takes into account that factor. Our work here sets all the assumptions of Fisher but relaxes the source assumption by considering different pollution sources (however our work will focus only on taxis-motor sector)

3. Toward the use of emission taxes in Cotonou: Methodological approach

3.1 Theoretical model

We use a two steps method that consists of:

[3] He take the 4 pollutants that causes the so-called 'greenhouse-gases': carbon dioxide (CO_2), methane (CH_4), nitrous oxide (NO_2), and chlorofluorocarbons (CFC11 and CFC12)

-First, A general equilibrium model based on an earlier model of Fisher (1980), however the model is modified to take account of the data availability and to meet the real case of Cotonou. The objective here is to derive how the taxation/compensation must be designed.

-Secondly we use an optimal taxation model to derive the level of tax that should be charged to the taxi-motor men.

3.1.1 Taxation/compensation design model

Assumptions

- Let's assume n goods, m populations of Cotonou and h "motor-taxi", z other firms.
- We assume that the motor-taxis are the causer of a part of the pollutant emitting in Cotonou, which is clearly identifiable.
- We assume also that the ambient concentration in air pollutant across Cotonou is the same at any point.
- The utility function and the production function are well behaved.
- We index the production function *d=1* if it is a taxi-motor production function and *d=0* if it is the other firm production function.

The problem of the social planner (or the government) is:

$$Max\ U^1\left[X_{11}, X_{21}, \ldots, X_{(n-1)1}, X_{n1}(S)\right] \qquad (1)$$

$$\text{s.t}\quad U^j\left[X_{1j}, X_{2j}, \ldots, X_{(n-1)j}, X_{nj}(S)\right] \geq U^{j^*} \qquad j = 2,3, \ldots, m \qquad (2)$$

$$f^{dk}(T_{1k}, T_{2k}, \ldots, T_{nk}, S_{dk}) = 0 \qquad k = 1,2, \ldots \ldots, h+z \qquad (3)$$

$$\sum_{j=1}^{m} X_{ij} - \sum_{1}^{h} T_{ik} = r_i \qquad (4)$$

$U^j = Utility\ of\ individual\ j$

$S = Smoke\ externality \quad S = \sum S_{1k} + \sum S_{0k}$

$X_{ij} = All\ the\ factor\ i\ that\ influence\ the\ utility\ of\ individual\ j$

$f^k = Taxi - motor\ man\ k\ production\ function\ in\ implicite\ form$ this function contains the smoke variable

T_{ik} = is the amount of services or resources i produced or consumed

S_{1h} = Smoke emitted by taxi-motor man h

$S_{0z} = Smoke\ emitted\ by\ the\ other\ firm\ z$

X_n= Health good depending on the smoke externality

- Equation (1) is the objective function; it is consumer 1 utility function and contains a smoke externality S
- (2) Says the utility of each consumer other than the one whose utility is being maximized must be at least equal to some level U^{j*}
- (3) Is a set of production motor-taxi-men production function
- (4) Is a set of other firms production function
- (5) is the resource/commodity constraint

The lagrangian gives:

$$L = U^1(.) + \sum_{j}^{m} \lambda_j [U^j(.) - U^{j*}] - [\sum_{k=1}^{h} \mu_{dk} f^{dk}(.)] + \sum_{1}^{m} \delta_i [r_i - \sum X_{ij} + \sum T_{ik} \quad (5)$$

The first order conditions give:

Differentiate with respect to X_{ij} gives:

$$\lambda_j \frac{\partial U^j}{\partial X_{ij}} - \delta_i = 0 \qquad (6)$$

Differentiate with respect to T_{ik} gives:

$$-\mu_{dk} \frac{\partial f^{dk}}{\partial T_{ik}} + \delta_i = 0 \qquad (7) \quad \forall\, i\ and\ k$$

Differentiate with respect to smoke of the taxi-moto gives

$$\sum_j^m \lambda_j \frac{\partial U^j}{\partial X_{nj}} \frac{\partial X_{nj}}{\partial S} - \mu_{1k} \frac{f^{1k}}{\partial S} = 0 \qquad (8)$$

Differentiate with respect to the smoke of the others firm gives:

$$\sum_j^m \lambda_j \frac{\partial U^j}{\partial X_{nj}} \frac{\partial X_{nj}}{\partial S} - \mu_{0k} \frac{f^{0k}}{\partial S} = 0 \qquad (9)$$

- We assign to each consumer and firm (non polluter firm and motor taxi) tax or compensation depending on the smoke damaged suffered or smoke damage caused. Let t^j and t^{1k} and t^{0k} represent the tax/compensation for the consumer and the motor-taxi and the other firms respectively.

- The program of the consumers (any individual in Cotonou) becomes:

  Before derive the consumer program let's write it budget constraint:

- Assuming that the consumer consumes $n^1 < n$ of the *n* goods so that n^1+1 to *n* services or goods are sold.

His expenditure is = $\sum_1^{n^1} P_i X_{ij}$

And his income is = $-\sum_{n^1+1}^{n} P_i X_{ij} + t^j$

The budget constraint becomes: $\sum_1^{n^1} P_i X_{ij} = -\sum_{n^1+1}^{n} P_i X_{ij} + t^j$

So $\sum_1^{n} P_i X_{ij} = t^j$ (10)

We can then write the program as:

$$Max\ U^j$$

$$\sum_1^n P_i X_{ij} = t^j$$

The first order conditions give[4]

$$L^j(.) = U^j(.) + \alpha_j\left(t^j - \sum P_i X_{ij}\right) \qquad (11)$$

$$\frac{\partial U^j}{\partial X_{ij}} + \alpha_j\left(\frac{\partial t^j}{\partial X_{ij}} - P_i\right) = 0 \qquad \forall\ i\ and\ k \ \ (12)$$

- The Producer program is:

The problem for them is to maximize profit subject to the production constraint

✓ The motor-taxi

$$L^{1k}(.) = \sum_1^n P_i T_{ik} \quad t^{1k} S_{1k} \quad \beta^{1k} f^{1k} \qquad (13)$$

The first order conditions give
Differentiate with respect to T_{ik} and S_{1k} give

$$P_i - \beta^{1k}\frac{\partial f^{1k}}{\partial T_{ik}} - 0 \qquad (14)$$

[4] Differentiate with respect to X_{ij}

$$-t^{1k} - \beta^{1k} \frac{f^{1k}}{\partial S_{1k}} = 0 \qquad (15)$$

✓ The other firms

$$L^{0k}(.) = \sum_{1}^{n} P_i T_{il} - t^{0k} S_{0k} - \beta^{0k} f^{0k}$$

Differentiate with respect to T_{ik} and S_{0k} give:

The first order conditions give

$$P_i - \beta^{0k} \frac{\partial f^{0k}}{\partial T_{il}} = 0 \qquad (16)$$

$$-t^{0k} - \beta^{0k} \frac{f^{0k}}{\partial S_{0k}} = 0 \qquad (17)$$

For the set of equations from (6) to (17) to be the same[5] we need to have:

$$t^{1k} + t^{0k} = -\sum_{j}^{m} \lambda_j \frac{\partial U^j}{\partial X_{nj}} \frac{\partial X_{nj}}{\partial S} \qquad (i)$$

$$\frac{\partial t^j}{\partial X_{ij}} = 0 \qquad (ii)$$

- (i)) Says that the sum of the tax that should be charged to the motor taxi and the others firms, must be equal to the marginal health degradation caused at the optimal level of emission.
- (ii) Implies the victims (any individual living in Cotonou) should not be taxed, but neither should he be paid any compensation –based on the amount equivalent to the damage they suffer.

From now our concern consist of deriving the marginal health degradation caused at the optimal level of emission.

3.1.2 Model of optimal taxation

The basic theory of optimal environmental taxation was worked out by Agnar Sandmo in an article in the Swedish Journal of Economics in 1975. Some points that have emerged from Sandmo's work are the following:

[5] We focus only on the important results from policy viewpoint

There is an “optimal” level of taxation on commodities, including those which generate pollution. The optimal level of taxation is determined by the government’s overall revenue needs, the market characteristics of each commodity, and the externalities generated by the commodity.

The basic Sandmo’s formula is:

Optimal Tax (%) = (1-a) ´ [Revenue Portion] + a ´ [Marginal Damages] (18)

There are 2 parts to the tax, the “Revenue Portion” and “Marginal Damages.” The first portion is determined strictly by the need to raise revenue, and the second is determined strictly by environmental considerations. The two parts should be considered separately.

Each part is weighted by a parameter “*a”*.

“a” is the inverse of the “Marginal Cost of Public Funds.”

The marginal cost of public funds is the amount of economic activity lost when the government increases its tax take from the economy by $1. It is usually assumed to be about 1.25—1.40, based on empirical works done in the 1980’s. This means that the economy loses about $1.25 in economic activity for every $1 additional revenue taken by the government.

Thus “a” would equal 1/1.25 = 0.8

As the government’s total revenue requirement goes up, the marginal cost of public funds rises and therefore *a* falls. Thus, *the heavier the economic burden of the general tax system, the less the rationale for green taxes. Also, the less the overall burden of the tax system, the greater the rationale for green taxes.*

“Marginal Damages” represents the total amount that people who are fully-informed about the effects of the pollution would be willing to pay to reduce emissions by one unit, if they had the option to go into a market and buy such emission reductions. If a particular pollutant is hardly noticeable or has little effect, people won’t be willing to pay to avoid exposure to it. If a pollutant is quite irritating or hazardous people might collectively be willing to give up a great deal of their economic welfare to reduce exposure. The “economic” approach to pollution control recognizes that markets which would allow people to express their preference for cleaner air, water etc. are very incomplete. Green taxes should simulate the prices that would emerge in a proper competitive market.

3.2 Data and sources

Our data come from the Ministry of environment data file, the World

Health Organization[6] data file and from the WB survey[7]. Here is the summarizing of our data.

Taxi motor number	80.000
Total Emission CO (TE) (Carbon Monoxide)[8]	83 tonnes/day
Contribution of Taxi Motor (CTM) in the overall pollution	49 tonnes/day
Average distance driving by a Taxi Motor per day	125km
Health care (D) expenditure due to the pollution	20 billions FCFA

3.3 Derivation of the taxation level

Our model is based on Sandmos's model; we modified his model to adapt it to the availability of data and to meet the own reality of Cotonou. To deal with the availability of the data problem, let's assume that the health degradation due to the emission is equivalent to the health care expenditure due to the pollution. This is conforming to the willingness to accept theory.

Assume that the damage cost due to pollution in Cotonou is equal to the expenditure in Health care. According to the World Bank study in 2002[9] the cost of respiratory ailments was analytically evaluated at approx. 20 billion CFA per year.

We must derive the marginal damage of pollution in Cotonou
Let D=20 billion
The overall damage per day is *Cd*

$$Cd = \frac{D}{12*30} = 55555556$$

CTM in percentage is equal to [49/83]*100 = 53.03%
According to the PPP and the general equilibrium model we derived, the taxi moto will charge 53,03%
Let md_t be this charge
md_t=[55555556*53.03]/100
=29461111 FCFA
md_t is equal to the marginal damage of pollution due to all the taxis-motor of Cotonou
Assuming that all the Taxi motor are identical, the marginal damage per taxi motor will be:
Md_k= md_t/80.000
=368 FCFA
Assuming that this marginal damage occurs after 125km (Average distance driving by a taxi-motor per day) the marginal damage per km is
Md= Md_k/125
= 3FCFA/km
Md is equal to the tax that should be charged to the taxi-motor per km, according to the

[6] Country press Releases WHO/AFRO March 2003
[7] http://www.worldbank.org/afr/findings
[8] there are also others emission for example, H_2, NO_x, SO_2 we are concern here about the most represented CO
[9] http://www.worldbank.org/afr/findings

model we derived; this tax is equal to the marginal health damage caused per km.
Using Sandmo's model and the marginal cost of public funds (presented in the methodological approach), the emitting tax must be:

$md_c = 0.8*3$

$md_c = 2.4$ FCFA

md_c represent for Cotonou the marginal damage chargeable per km.

3.4 Simulations:

Let's assume this model to make some simulations to see the behavior of the tax system

$$\textbf{Tax= E*D*} \, md_c$$

Where D is the total distance driven since the last control[10]

E is the emission class from 0 to 3, with 0 being the cleanest and 3 being the dirtiest per km[11]

Assuming that the taxi-motor X belongs to class 3 and has driven 10.000 km, his fees will equal to

fee_x= 1.5*10.000*2.4

= 36.000 FCFA

Suppose taxi-moto Y has driven the same amount, but has rated E= ½ his fees or tax will be:

fee_y= ½ *10.000*2.4

= 12.000 FCFA

Knowing they will face these kind of fee, they have an incentive to drive less, get they motorbike turned up to a lower emissions class, or get a cleaner type of motorbike if they have to drive that much.

4. Effects of that Policy and Conclusion

The incentives created by such a pricing scheme would be:

- Those who drive a lot will tend to buy low emission motorbike
- High-emission motorbike would be allocated through the used motorbike market in the hands of people who either live in low-damage areas (i.e. rural and remote area that don't have air quality problems) or who drive very little.
- Mechanics would find growing demand from motorbike owners on maintenance options to keep vehicles in a lower emissions class.
- Regardless of the motorbike emission class, all motorbike owners would have a continuous incentive to economize on distance traveled. This may translate into increased ridership on public transit, and elimination of the most frivolous motorbike trips.

To be efficient this scheme of tax should be apply to all vehicle in Cotonou, to do so, this study should include the motorbike that are not Taxi moto, and all the vehicle. Once apply this tax scheme will help to develop public or common transport and hence achieve the goal of reduction

[10] Another work can interest in the optimal number of control per year.

[11] These measures here are completely ad-hoc and can be done by the ABE with his specialized garages SOBEPAT, WCM-BENIN, Auto star and Mutuelle confiance (in DSRP- 2005)

of the pollution. In a wide study, one should include the heterogeneity in the damage through Cotonou.

Such a pricing scheme would have to be coordinated among the Ministry of finance, Ministry of transport, ABE, and the commune of Cotonou. These services should create program that would automatically generate the information needed to assess this policy effectiveness.

One weakness of this work was to suppose one pollutant (CO) this choice was based on the availability of the data. In a number of important cases of pollution problems, an undesirable environmental effect is brought about by a number of pollutants, which jointly produce the effect. In Cotonou except CO there is also pollution due to H_2, NO_x, SO_2. Michaelis (1992) suggest considering the problem in the framework of multiple pollutants taxes.

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