Journal of Economic Science Research
http://ojs.bilpublishing.com/index.php/jesr

ARTICLE

Management of Air Pollution by a System of Transferable Individual Emission Permits with Overlapping Generations

Tchousso Adamou*

Faculty of Economics and Management, Abdou Moumouni University, Niamey, Niger

ARTICLE INFO

Article history
Received:3 January 2019
Accepted: 7 January 2019
Published: 7 March 2019

Keywords:
Atmospheric pollution
Overlapping generations
Individual permits
Overlapping generations
JEL:
Q53, Q56

ABSTRACT

The purpose of this article is to analyze the effectiveness of a pollution management system through individual permits that are distributed to young people with overlapping generations. From a general equilibrium model, the results show that such a system provides the conditions for optimal pollution management. But because of the non-cooperative behavior of the actors, this policy cannot institute intergenerational altruism. Incentives such as tax or subsidy are needed to get the receiving population to better choose between the physical good whose production satisfies their needs and the quality of the environment that depends on their option to sell the permits to firms or the future generation.

1. Introduction

The main objective of this paper is to analyze the efficiency of a system of management of air pollution by individual licenses distributed to the youth with overlapping generations. According to Bonnieux and Desaigues [2], there is pollution when the following two conditions are met:

(1) Identification of the effect on the environment which can be physical (discharges of the various substances), biological (effects on mortality of animal species, on human health), chemical (acid rains, contamination of the environment), noise effect;

(2) Observation of human reactions which translates a dislike, a nuisance, a concern, a discouragement or anxiety, causing a loss of well-being thus disutility.

Whatever form it takes, air pollution is a negative external effect that results in three disabilities according to Chanel et al. [5]. First, pollution has direct non-health effects such as degradation of sensory perceptions. Next, indirect non-health effects like deterioration of the flora and fauna may be the consequence of pollution. Finally, pollution has direct health effects such as mortality and morbidity (hospitalization and diseases).

These various effects negatively impact individual utility functions and the collective well-being according to their scope as in the case of climate change. They cause an environmental management problem of repairing or even eradicating the damage caused by society's collective activities. In this sense, various instruments ranging

**Corresponding Author:*
Tchousso Adamou,
Faculty of Economics and Management, Abdou Moumouni University, Niamey, Niger
E-mail: adamoutchousso@yahoo.com

DOI: https://doi.org/10.30564/jesr.v2i1.449

from consensual to more radical can be applied depending on the context. Opinions are divided as to the responsible participation of citizens in the management of the environment, given that the decisions of the current generation will irrevocably have an impact on the well-being of future generations. This article aims to analyze the management of air pollution by individual transferable licenses with overlapping generations (ITL /OG).

The balance of this research is organized as follows. Section 2 discusses the various instruments available for the management of the environment. Section 3 presents a detailed analysis of the of PIT/GI model. Finally, Section 4 presents our conclusion.

2. Environmental Management Instruments

Environmental management involves the application of two main groups of instruments: direct controls and incentives (or economic). Direct controls, referred to as regulatory instruments, derive from the normative and legal approach to environmental policy Prieur [21]. They translate into norms, prohibitions, or pressure groups (John and Pecchenino [13], John et al. [12], Zhang [25], and Bürgenmeir [4]). However, they may be the only ones applicable in certain urgent cases even though they are criticized for the lack of incentive for the emitter of the pollution to reduce its discharges (Beaumais and Chiroleu-Assouline [1]). The norm in particular is sometimes criticized because of its arbitrary and one-sided nature. It degrades the competitiveness of some companies causing fraud or relocation.

Incentive instruments, also known as economic instruments, result in taxes, subsidies or royalties. Taxes have the added advantage of generating revenue for governments. By contrast, subsidies are awarded to polluters as compensation for the loss of earnings caused by the limitation of their production, the source of emission of pollutants. It is widely recognized that economic instruments, once accepted, are easier to apply than the standards. That is because polluters may find it beneficial to innovate in order to decrease pollution and profit from the ensuing financial incentives[1]. On the other hand, taxes almost never result in a reduction in the volume of the pollution for which no threshold is fixed a priori and present the risk of degrading the purchasing power of consumers by affecting selling prices.

The market for the right to pollute is another instrument of environmental management. It was proposed by Dales [6] and consists of issuing titles (certificates or permits or quotas) each containing the right to emit a certain quantity of pollutants. In principle, obtaining a certificate is subject to a price expressing the social costs in monetary value. The market is established between economic actors who sell and buy the certificates. The total volume of pollution to be rejected is fixed in advance. The freedom of choice is thus respected, and the industrialists return to their usual activities of exchange (Bürgenmeir [4]). This principle is called blasphemous by some actors. In addition, agents may purchase permits with the sole purpose of erecting barriers to entry into the market or curbing productive activity by hoarding them (Vallée [24]). The establishment of emission permits is not primarily about creating a right to pollute where there was none. On the contrary, this right is restricted whereas, if not, it was unlimited (De Perthuis and Boccon-Gibord [7]). The environmental regulator is the only authority to set the overall emission ceiling. Permits can be distributed for free or for a fee. The free distribution made according to the past level of emissions is known as the grandfathering method whereas the one made according to the past level of production of a reference period is called the benchmarking method (Schwartz [22]).

These instruments have in common the repair of the environmental damage by the one who causes it, it is the Polluter Pays Principle (PPP). PPP is the principle of internalization that enjoys the greatest acceptability because it restores the truth about costs rather than simply accounting for individual charges (Bürgenmeir [4]). It aims at internalizing external costs in the calculation of production costs. This involves ensuring that the producer includes in his costs all the expenses related to the prevention, control and reduction of pollution. The effectiveness of this principle, described as "politically correct" (Godard [9]), is not always accepted by environmental advocates. By paying, the polluter is not encouraged to reduce his emissions because his behavior is likely driven by the sign of his marginal profit. Some advocate that the market system for permits, which also allows the polluter to pay in advance, is preferable to the PPP in its strict sense. Unlike taxes, license exchange markets offer those interested in working for the environment the opportunity to do so by buying and retiring permits. Ethics based on a postulate of freedom and sovereignty (Mekni [17]) recommends the authorization of citizens to participate in the market. The quality of the environment of interest to all several sectors of the economy and several human generations. To this end, it constitutes general equilibrium conundrum.

1 Some environmental defenders blame subsidies for attracting polluters rather than dissuading them (Vallée [24]).

John and Pecchenino [13] developed a general equilibrium model with environment and overlapping generations. Agents derive satisfaction from the consumption of a physical good as well as the quality of the environment. However, their consumption degrades the quality of the environment to be transmitted to future generations. Each agent accumulates capital and environmental quality. There is then an arbitration between saving and maintaining the environment. Increasing savings benefits future generations through the returns it provides. This decision, on the other hand, leads to a decrease in environmental quality concomitantly with an increase in consumption.

Michel et al. [19] established another growth model with a natural environment. Environmental problems are those of pollution or the exploitation of natural resources. They affect current and future generations. In the area of renewable natural resources, Mahé and Ropars [16] demonstrated the effectiveness of the system of individual transferable quotas (ITQs) rather than regulation by restricting a factor of production on the farm. Jouvet and Rotillon [14] reached the same conclusion by adding a system of overlapping generations in the case of the exploitation of a common renewable natural resource.

For the specific case of the environment, Prieur [21] analyzed the management of pollution by a central regulatory agency through permits. This author, however, does not analyze the case of individual transferable quotas. Also, in Prieur's approach, households participate in the pollution permit market by purchasing them rather than receiving them free of charge. The effectiveness of the principle of individualization of rights has also been demonstrated by Buisson and Barnley [3]. Their study showed that the importance of ITQs for the sustainable management of fisheries resources in France lies first in their individual character and then in their transferability. But their model did not have overlapping generations.

Inspired by John and Pecchenino [13], John et al. [12], and Zhang [25], Fodha [8] also analyzed pollution management in an overlapping generations model and found that when depollution activity is within the reach of households through a trade-off between physical capital and green capital, individual commitment is not always enough to return to the standard of efficiency. Individual concerns are rather motivated by a selfish argument. The participation of other stakeholders interested in the environment such as Non-Governmental Organizations (NGOs) may be considered.

The participation of environmental NGOs in the emission permit market consists of the purchase and withdrawal of permits. In this way, they hope to cause tariffs to become scarcer so as to cause their prices to rise and encourage firms to make more clean-up efforts. However, these NGOs do not always have enough resources compared to issuers (Kollmus and Lazarus [15]). Noticeably, Mekni [17] discourages citizen participation in license markets for the following three reasons:

1) because the environment is a public good by reason of the rationality and egoism, stowaway behavior is a likely outcome.

2) if the emission permits were initially allocated to the polluters, each citizen will embrace stowaway behavior by not buying or by purchasing too few licenses, relying on others to fight against pollution;

3) if permits are initially allocated to citizens, everyone is encouraged to sell most of their permits, thus relying on others to fight against pollution.

The auction of emission permits allows the formation of a market price and helps the disclosure of private information held by the regulatory agent. It also avoids the problem of dealing with companies that close and disadvantages a wait-and-see behavior (Schwartz [22]). However, free distribution is the most widely used medium for allocating emission permits (Svendsen [23], Hanoteau [10], and Schwartz [22]). The free allocation is proof of acceptance by issuers to be subject to the licensing market. It favors the transition from a situation where the pollutant is not regulated to a situation where it becomes (Schwartz [22]).

Unlike noise pollution, air pollution accumulates and as a result, it impacts the quality of the environment transferred in an intergenerational framework. It would therefore be interesting to empower each individual citizen in the management of the common natural asset. In this sense, the following section proposes to analyze this form of participation of each citizen in the management of air pollution by means of permits received at an early age and freely sold only at retirement to polluters or to the future generation.

3. Individual Transferable Licenses with Overlapping Generations and Capital

The assumptions of the model are first presented before analyzing its results.

3.1 The Assumptions of the Model

It is assumed a production economy with pollution in which an official entity is responsible for the management of the environment as in the case of Prieur [20]. We assume in each period a free distribution of all licenses to young people rather than sell them. There is no distribution of environmental rent. Each consumer lives two periods.

DOI: https://doi.org/10.30564/jesr.v2i1.449

During the first period, he/she is active and his/her income consists of a salary. Retirement occurs in the second period of life and income is drawn from the sale of the permits owned and the return on monetary savings accumulated during the active period. The environmental regulator establishes a principle by means of a code rendering the permits issued non-transferable. Thus, only a young person can buy permits, but he /she can only sell them in retirement. The purpose of this provision is to be able to postpone licensing for a period of time and thus delay the emission of pollutants. In more detail, the model is based on the following conditions:

• the maximum amount of pollution to be emitted by a nation is set by international environmental organizations (FME, IUCN, UN, etc., for example). At each date (t), the regulator converts this volume by issuing a quantity $\overline{P}_t$ of pollution permits which is distributed to the young people of the period;

• at each date (t), a generation of N_t identical individuals are born. The population grows at the constant rate of (n). Thus, $N_t = (1+n)N_{t-1}$;

• in a competitive sector, firms use physical capital (K), environment (E) and labor (L) to produce a quantity of goods that equals (Y);

Production is defined by:

$$Y_t = F(K_t, E_t, L_t) \cdots\cdots\cdots (1)$$

for every i , $F_{ii} < 0$ and for every $j \neq i$, $F_{ij} > 0$

At the level P_t of the environment, the volume of pollution is noted and is part of the dynamics:

$$P_t = P_{t-1} - R(P_{t-1}) + E_t \cdots\cdots\cdots (2)$$

• R ( ) is the function of recycling the environment with $R(0) = 0$;

It exists $\widehat{P} > 0$ such as: $R'(\widehat{P}) = 0;$

$$R'(P) > 0 \text{ if } P < \widehat{P} \text{ and } R'(P) < 0 \text{ if } P > \widehat{P};$$

There is $Z > \widehat{P}$ as $R(Z) = 0; Z$ is the stable equilibrium of the natural environment in the absence of any pollutant discharge;

E_t : the emission of pollutants (in giga grams) during the productive activities of firms.

The agent's salary ω_t is recorded during the active period. This income is divided between:

• the consumption of a homogeneous final good c_t;

• the constitution of monetary savings s_t;

• the purchase of a quantity p_{t-1} of emission permits from the old of the period at the unit price of q_t :

$$Q_t = q_t p_{t-1} \quad \cdots\cdots\cdots (3)$$

So, we have: $\omega_t = c_t + s_t + Q_t \quad \cdots\cdots\cdots (4)$

The number of permits received by each young person is denoted as $\overline{p}_t$, so we have:

$$\overline{p}_t = \overline{P}_t / N_t \quad \cdots\cdots\cdots (5)$$

The total number of permits each youth has at time (t) becomes:

$$\Omega_t = p_{t-1} + \overline{p}_t \quad \cdots\cdots\cdots (6) \; ; \; \Omega_t > 0$$

The conditions for optimum growth are deduced as explained below.

3.2 The Social Optimum

Consumer preferences are represented by the utility function:

$$U_t = U(c_t, \mathrm{P}_t, d_{t+1}, \mathrm{P}_{t+1}) \quad \cdots\cdots\cdots (7)$$

Uc <0, Up<0 and Ucp <0

$U(\ )$ is strictly concave, twice differentiable and satisfies the conditions of Inada:

$$U(0) = 0; \; U'(0) = \infty \text{ et } U'(\infty) = 0$$

d_{t+1} : consumption of the agent born in (t) at the second period (retirement), one has:

$$d_{t+1} = T_{t+1} s_t + \left[\alpha_{t+1}\phi_{t+1} + (1-\alpha_{t+1}) q_{t+1}\right] \Omega_t \quad \cdots\cdots\cdots (8)$$

T_{t+1} : the capitalization factor (or return) of the savings invested in $(t+1)$;

$\alpha_{t+1} \in [0,1]$ is the coefficient of distribution of permits between the production process (firms) and the sale to the future generation. Therefore,

• when the agent sells all his licenses to the future generation at the unit price of q_{t+1}, then $\alpha_{t+1} = 0$;

• on the other hand, when the agent sells all his licenses to firms at the unit price of ϕ_{t+1}, then $\alpha_{t+1} = 1$.

P_{t+1} : the volume of pollution in the period $(t+1)$;

The regulator maximizes the sum of the utilities of the generations considering a discount rate $\gamma \in]0,1[$ to ensure optimal growth. At the macroeconomic level, in equilibrium one must check the equality between total consumption, investment demand and total production, that the following equality must hold:

$$Y_t = F(K_t, E_t, L_t) = N_t c_t + N_{t-1} d_t + K_{t+1} \quad \cdots\cdots\cdots (9)$$

d_t : consumption of retirees of the period (t);

K_{t+1} : the capital stock in $(t+1)$.

The regulator's program consists in maximizing the welfare of the agents by choosing consumption levels c_t and d_t, polluting emissions E_t under the constraints of the production and the quality of the environment (volume of pollution). From the utility function (7) and the model accumulation variables, which are the capital K_t and the quality of the environment P_t, we set the following program:

$$Max\sum_{t=-1}^{\infty}\gamma^t N_t U_t$$

$$s/c\begin{cases}Y_t = N_t c_t + N_{t-1}d_t + K_{t+1}\\ P_t = P_{t-1} - R\left(P_{t-1}\right) + E_t\end{cases}$$

The Lagrangian of this program is as follows.

$$\begin{aligned}L(\ ) = {} & \gamma^{t-1}\left\{N_{t-1}U_{t-1}\left(c_{t-1},\mathrm{P}_{t-1},d_t,\mathrm{P}_t\right)+\lambda_{t-1}\left(Y_{t-1}-N_{t-1}c_{t-1}-N_{t-2}d_{t-1}-K_t\right)+\mu_{t-1}\left(P_{t-1}-P_{t-2}+R\left(P_{t-2}\right)-E_{t-1}\right)\right\}+\\ & \gamma^{t}\left\{N_tU_t\left(c_t,\mathrm{P}_t,d_{t+1},\mathrm{P}_{t+1}\right)+\lambda_t\left(Y_t-N_tc_t-N_{t-1}d_t-K_{t+1}\right)+\mu_t\left(P_t-P_{t-1}+R\left(P_{t-1}\right)-E_t\right)\right\}+\\ & \gamma^{t+1}\left\{N_{t+1}U_{t+1}\left(c_{t+1},\mathrm{P}_{t+1},d_{t+2},\mathrm{P}_{t+2}\right)+\lambda_{t+1}\left(Y_{t+1}-N_{t+1}c_{t+1}-N_td_{t+1}-K_{t+2}\right)+\mu_{t+1}\left(P_{t+1}-P_t+R\left(P_t\right)-E_{t+1}\right)\right\}\end{aligned}$$

$\lambda_j;\ j=\left(t-1\right),\left(t\right)$ and $\left(t+1\right)$ the Lagrange multipliers associated with the stock of production;

$\mu_j;\ j=\left(t-1\right),\left(t\right)$ and $\left(t+1\right)$: the Lagrange multipliers associated with the volume of pollution.

After resolution, as conditions of first order we have:

• Optimal consumption of young people of the period $\left(t\right)$

$$\frac{\partial L(\ )}{\partial c_t}=0\Rightarrow\frac{\partial U_t}{\partial c_t}=\lambda_t\ldots\ldots\ldots(10)$$

• The optimal consumption of old people of the period $\left(t\right)$

$$\frac{\partial L(\ )}{\partial d_t}=0\Rightarrow\frac{\partial U_{t-1}}{\partial d_t}=\gamma\lambda_t\ldots\ldots(11)$$

• The optimal emission of pollutants for production needs

$$\frac{\partial L(\ )}{\partial E_t}=0\Rightarrow\lambda_t F_{E_t}=\mu_t\ldots(12)$$

These conditions should be used to characterize the various transactions made in the economy from the previous Lagrangian:

• The transaction between generations stems from (10) and (11):

$$\gamma\frac{\partial U_t}{\partial c_t}=\frac{\partial U_{t-1}}{\partial d_t}\ldots\ldots\ldots(13)$$

• The intertemporal distribution of consumption

$$\gamma\lambda_{t+1}\frac{\partial Y_{t+1}}{\partial K_{t+1}}=\lambda_t\ldots\ldots\ldots(14)$$

• Arbitration between the quality of the environment and the consumption of physical good:

$$\frac{\partial L(\ )}{\partial P_t}=0\Rightarrow\mu_t=\gamma\mu_{t+1}\left(1-R'\left(P_t\right)\right)-N_t\left(\frac{1}{\left(1+n\right)\gamma}\frac{\partial U_{t-1}}{\partial P_t}+\frac{\partial U_t}{\partial P_t}\right)\ldots\ldots\ldots(15)$$

$$\frac{\partial L(\ )}{\partial c_{t+1}}=0\Rightarrow\frac{\partial U_{t+1}}{\partial c_{t+1}}=\lambda_{t+1}\ldots(16)$$

$$\frac{\partial L(\ )}{\partial E_{t+1}}=0\Rightarrow\gamma^{t+1}\lambda_{t+1}\frac{\partial Y_{t+1}}{\partial E_{t+1}}-\gamma^{t+1}\mu_{t+1}=0\Rightarrow\lambda_{t+1}F_{E_{t+1}}=\mu_{t+1}\ldots\ldots(17)$$

The implicit price dynamics λ_t and μ_t are obtained as follows considering the conditions of positivity:

$$K_{t+1}\geq 0 \text{ and } P_t\geq 0\ \forall\left(t\right)$$

From $\dfrac{\partial L(\ )}{\partial K_{t+1}}=0,$ we get

$$\lambda_t=\gamma\lambda_{t+1}F_{K_{t+1}}\left(K_{t+1},E_{t+1},N_{t+1}\right)\ldots\ldots\ldots(18)$$

From $\dfrac{\partial L(\ )}{\partial P_t}=0,$ we get

$$\mu_t=\gamma\left(1-R'\left(P_t\right)\right)\mu_{t+1}-N_t\left(\frac{1}{\left(1+n\right)\gamma}\frac{\partial U_{t-1}}{\partial P_t}+\frac{\partial U_t}{\partial P_t}\right)\ldots\ldots(19)$$

The transversality condition (Michel [19]) is:

$$\lim_{t\to\infty}\gamma^t\left(\lambda_tK_t+\mu_{t-1}P_{t-1}\right)=0\ldots\ldots\ldots(20)$$

The individual permit system results in a balancing economy as follows.

3.3 The Balance with Individual Transferable Pollution Permits

According to the Cournot-Nash approach, an agent considers the externality corresponding to his decision to sell to the firms his licenses by assuming the behavior of the other agents $\left(\overline{E}_{t+1}\right)$ as a given. The dynamics of pollution can be written as follows:

$$P_{t+1}=P_t-R\left(P_t\right)+\alpha_{t+1}\Omega_t+\overline{E}_{t+1}\ldots\ldots\ldots(21)$$

Each consumer's program is as follows:

$$\max_{c_t,d_{t+1},s_t,\mathrm{p}_{t-1},\alpha_{t+1}}U\left(c_t,\mathrm{P}_t,d_{t+1},\mathrm{P}_{t+1}\right)$$

$$\begin{cases}c_t=\omega_t-s_t-Q_t\\ d_{t+1}=T_{t+1}s_t+\left[\alpha_{t+1}\phi_{t+1}+\left(1-\alpha_{t+1}\right)q_{t+1}\right]\Omega_t\\ P_{t+1}=P_t-R\left(P_t\right)+\alpha_{t+1}\Omega_t+\overline{E}_{t+1}\end{cases}$$

The Lagrangian of this program is as follows:

$$\begin{aligned}L(\ )= {} & U\left(c_t,\mathrm{P}_t,d_{t+1},\mathrm{P}_{t+1}\right)+\lambda_1\left\{c_t-\omega_t+s_t+p_{t-1}q_t\right\}+\\ & \lambda_2\left\{d_{t+1}-T_{t+1}s_t-\left[\alpha_{t+1}\phi_{t+1}+\left(1-\alpha_{t+1}\right)q_{t+1}\right]\Omega_t\right\}+\\ & \lambda_3\left\{P_{t+1}-P_t+R\left(P_t\right)-\alpha_{t+1}\Omega_t-\overline{E}_{t+1}\right\}\end{aligned}$$

λ_1,λ_2 and λ_3 the multipliers of Lagrange.

The first order conditions resulting from the resolution are:

  DOI: https://doi.org/10.30564/jesr.v2i1.449

- $\frac{\partial L(\ )}{\partial c_t}=0\Rightarrow\frac{\partial U_t}{\partial c_t}=-\lambda_1\ldots\ldots(22)$
- $\frac{\partial L(\ )}{\partial s_t}=0\Rightarrow\lambda_1-\lambda_2T_{t+1}=0\Rightarrow\lambda_1=\lambda_2T_{t+1}\Rightarrow\frac{\partial U_t}{\partial c_t}=-\lambda_2T_{t+1}\ldots\ldots(23)$
- $\frac{\partial L(\ )}{\partial d_{t+1}}=0\Rightarrow\frac{\partial U_{t+1}}{\partial d_{t+1}}+\lambda_2=0\Rightarrow\frac{\partial U_{t+1}}{\partial d_{t+1}}=-\lambda_2\ldots\ldots\ldots(24)$
- $\frac{\partial L(\ )}{\partial\alpha_{t+1}}=0\Rightarrow\left[-\lambda_2\phi_{t+1}+\lambda_2q_{t+1}\right]\Omega_t-\lambda_3\Omega_t=0$

$$\Rightarrow\lambda_2\left[q_{t+1}-\phi_{t+1}\right]-\lambda_3=0\Rightarrow\lambda_3=\frac{\partial U_{t+1}}{\partial d_{t+1}}\left[\phi_{t+}-q_{t+1}\right]$$

- $\frac{\partial L(\ )}{\partial P_{t+1}}=0\Rightarrow\frac{\partial U_{t+1}}{\partial P_{t+1}}+\lambda_3=0\Rightarrow\lambda_3=-\frac{\partial U_{t+1}}{\partial P_{t+1}}$

From (23) and (24) we get

$$\frac{\partial U_t}{\partial c_t}=\frac{\partial U_{t+1}}{\partial d_{t+1}}T_{t+1}\Rightarrow T_{t+1}=\frac{\partial U_t/\partial c_t}{\partial U_{t+1}/\partial d_{t+1}}\ldots\ldots\ldots\ldots(25)$$

$$\lambda_3=\frac{\partial U_{t+1}}{\partial d_{t+1}}\left[\phi_{t+}-q_{t+1}\right]$$

$$\left[q_{t+1}-\phi_{t+1}\right]=\frac{\frac{\partial U_{t+1}}{\partial P_{t+1}}}{\frac{\partial U_{t+1}}{\partial d_{t+1}}}\ldots\ldots\ldots(26)$$

$$\frac{q_{t+1}}{q_t}=\frac{\frac{\partial U_t}{\partial c_t}}{\frac{\partial U_{t+1}}{\partial d_{t+1}}}\ldots\ldots\ldots\ldots\ldots(27)$$

To simplify, we note: $\frac{\partial U_t}{\partial c_t}=U_{c_t}$; $\frac{\partial U_{t+1}}{\partial d_{t+1}}=U_{d_{t+1}}$ and $\frac{\partial U_{t+1}}{\partial P_{t+1}}=U_{P_{t+1}}$

The results of (25),(26) and (27) make possible to establish the relations hereafter.

$$\begin{cases}\frac{U_{c_t}}{U_{d_{t+1}}}=T_{t+1}\ldots\ldots\ldots\ldots(28)\\ \frac{U_{c_t}}{U_{d_{t+1}}}=\frac{q_{t+1}}{q_t}\ldots\ldots\ldots\ldots(29)\\ q_{t+1}=\phi_{t+1}+\frac{U_{P_{t+1}}}{U_{d_{t+1}}}\ldots\ldots(30)\end{cases}$$

The arbitration condition (28) and (29) is derived from the distribution of savings between capital and permits: $\frac{q_{t+1}}{q_t}=T_{t+1}\ldots\ldots\ldots(31)$

The condition of arbitration (30) is drawn between the users of the permits. Let's recall that $U_{P_{t+1}}<0$ because it is a disutility. $\left[\phi_{t+1}-q_{t+1}\right]\geq 0$ shows that, a priori, each actor is encouraged to sell to firms with the intention of maximizing his gain. This decision favors the deterioration of the quality of the environment, illustrating that individual rationality generates collective malaise, that is, the tragedy of commons[11]. Air pollution is indeed most often a pure public evil. Incentive mechanisms such as taxes, subsidies or fees should be instituted to encourage the transmission of better environmental quality to the next generation.

When $U_{P_{t+1}}=0$ prices become equal and the agent becomes indifferent between selling his licenses to firms and to the future generation.

In the case of firms for which the objective is profit maximization, we have:

$$\pi_t=F\left(K_t,E_t,L_t\right)-r_tK_t-\phi_tE_t-\omega_tL_t\ldots\ldots(32)$$

Where r_t, ϕ_t and ω_t is return on capital, unit price of pollution permits, and salary, respectively. At the competitive equilibrium, we have:

- $r_t=F_K\left(K_t,E_t,L_t\right)\ \ldots\ldots\ldots(33)$;
- $\phi_t=F_E\left(K_t,E_t,L_t\right)\ \ldots\ldots\ldots(34)$;
- $\omega_t=F_L\left(K_t,E_t,L_t\right)\ \ldots\ldots\ldots(35)$.

The balance of the studied economy covers four markets namely: labor market, pollution permits, physical assets and capital. In each of these markets we are looking for equality between supply and demand. More concretely we have:

- In the labor market: at each date, under the assumption of an inelastic labor supply, the number of employees is equal to the number of young people in the economy $L_t=N_t\ldots\ldots\ldots\ldots(36)$,
- On the pollution permit market: in equilibrium, the number of permits requested by firms must be equal to the number directly offered by the old to the production process, hence:

$$E_t=N_{t-1}\alpha_t\left(p_{t-2}+\overline{p}_{t-1}\right)\ldots\ldots\ldots(37)$$

For licenses that are not exploited by firms and are therefore transferred to the next generation, the supply of old people of the period must be equal to the demand of

 DOI: https://doi.org/10.30564/jesr.v2i1.449

the young of the same period, hence:

$$N_{t-1}(1-\alpha_t)(p_{t-2}+\bar{p}_{t-1}) = N_t\left(\frac{Q_t}{q_t}\right) = N_t\frac{(\omega_t - c_t - s_t)}{q_t} = N_t p_{t-1}\cdots\cdots(38)$$

• In the physical goods market: the macroeconomic balance assumes the equality between total consumption, investment demand and total output from where:

$$Y_t = F(K_t, E_t, L_t) = N_t c_t + N_{t-1}d_t + K_{t+1}\ldots\ldots\ldots(39)$$

• On the capital market (balanced under the Walras law): investor demand is satisfied by the savings of old people constituted when they were active:

$$K_t = N_{t-1}s_{t-1}\ldots\ldots(40)$$

For a level $\bar{P}_t$ a balance of the economy is then defined as a sequence of:

• prices $(r_t, \phi_t, \omega_t), t \geq 0$;

• variables per capita $(c_t, s_t, p_{t-1}, \ _{t+1}, d_{t+1})$ meeting the budgetary constraints and the conditions of the economic agent's first order;

• $(K_t, E_t, L_t), t \geq 0$ aggregated variables satisfying the first order conditions $(33),(34)$ and (35) of the firms.

Given that the conditions of equilibrium are verified and accounting for the dynamics of the pollution, the optimal policy is obtained as explained below.

3.4 The Optimal Policy

In equilibrium, at each period (t), each young person receives from the regulator a quantity of pollution permits:

$$\bar{p}_t = \frac{\bar{P}_t}{N_t}\ldots\ldots\ldots(5)$$

• assuming an inelastic labor supply, at equilibrium in this market,

we have: $L_t = N_t\ldots\ldots\ldots(36)$

• in the capital market we have:

$$K_t = N_{t-1}s_{t-1} \quad \ldots\ldots\ldots(40)$$

• in the goods market, we have:

$$N_{t+1}c_{t+1} + N_t d_{t+1} = F(N_t s_t, N_t(p_{t-1}+\bar{p}_t - p_{t+1}), N_{t+1}) - K_{t+2} \quad \ldots\ldots\ldots(41)$$

• in the permit market there are two cases:

• the number of permits required by firms must be equal to the number offered for production purposes;

$$E_t = N_{t-1}\alpha_t(p_{t-2}+\bar{p}_{t-1})\ldots\ldots(42)$$

• the number of licenses sold to the future generation must be equal to the number surrendered in the speculation:

$$N_{t-1}(1-\alpha_t)(p_{t-2}+\bar{p}_{t-1}) = N_t\left(\frac{Q_t}{q_t}\right) = N_t\frac{(\omega_t - c_t - s_t)}{q_t} = N_t p_{t-1}\ldots\ldots(43)$$

Compared to the prices on the market of the permits not allocated to the production of $(29),(30)$ and (31), one draws:

$$q_{t+1} = q_t\frac{U_{c_t}}{U_{d_{t+1}}}\ldots\ldots\ldots(44)$$

$$q_{t+1} = F_{E_{t+1}}(N_t s_t, N_t(p_{t-1}+\bar{p}_t - p_{t+1}), N_{t+1}) + \frac{U_P(c_t, P_t, d_{t+1}, P_{t+1})}{U_d(c_t, P_t, d_{t+1}, P_{t+1})}\ldots\ldots(45)$$

Thus

$$q_{t+1} = q_t F_{K_{t+1}}(N_t s_t, N_t(p_{t-1}+\bar{p}_t - p_{t+1}), N_{t+1})\ldots\ldots(46)$$

At the intertemporal equilibrium, the dynamics of pollution deviate:

$$P_{t+1} = P_t - R(P_t) + N_t(p_{t-1}+\bar{p}_t - p_{t+1})\ldots\ldots\ldots(47)$$

We can now study the stationary equilibrium of the economy.

3.5 Stationary Balance

Given a stable level of a policy of individual transferable pollution permits: $\bar{P} = N\bar{p} < R(\hat{P})$ the stock of capital is given by the sum of the savings $K = Ns \quad \ldots\ldots\ldots(48)$ and by $\frac{q_{t+1}}{q_t} = T_{t+1}$ one draws the golden rule:

$$T^* = 1 \ \ldots\ldots\ldots(49)$$

Indeed, in the stationary state, $\frac{q_{t+1}}{q_t} = T_{t+1}$ becomes: $\frac{q}{q} = T \ = 1$ This factor of interest must correspond to the marginal productivity of capital.

Starting from $E_{t+1} = N_t(p_{t-1}+\bar{p}_t - p_{t+1})$, we infer that stationary equilibrium agents assign to firms the number of permits that have been distributed to them by the planner, hence: $N_t(p_{t-1}+\bar{p}_t - p_{t+1}) = \tilde{E}$.

$N_t(p_{t-1}+\bar{p}_t - p_{t+1})$ becomes: $N(p+\bar{p}-p) = N\bar{p}$;from where $\tilde{E} = N\bar{p} \quad \cdots\cdots\cdots(50)$

In this case, the stable level of pollution is deduced from: $P_t = P_{t-1} - R(P_{t-1}) + E_t$

becomes: $P = P - R(P) + \tilde{E}$ from where: $R(P) = \tilde{E}$

And we have:

$$R(P^*) = N\bar{p} \quad \cdots\cdots\cdots(51)$$

The price of permits in the financial market, from

DOI: https://doi.org/10.30564/jesr.v2i1.449

(45) becomes:

$$q^* = F_E\left(K, N\overline{p}, N\right) + \frac{U_P\left(d, N\overline{p}\right)}{U_d\left(d, N\overline{p}\right)} \quad \cdots\cdots\cdots(52)$$

From (9), the stationary consumption level becomes $Nc^* + Nd^* = F\left(K, N\overline{p}, N\right) - K$

At stationary equilibrium, one can attain the maximum possible utility of the economy. It is recalled that the central regulator's objective is to maximize the well-being of agents under the constraints of existing economic resources by choosing the optimal level of consumption, the quality of the environment and the level of capital. To do this, we ask the following program:

$$\max_{c,d,\mathrm{P},K} NU\left(c, \mathrm{P}, d, \mathrm{P}\right)$$

$$\begin{cases} Nc + Nd + K = F\left(K, N\overline{p}, N\right) \\ R\left(P\right) = N\overline{p} \end{cases}$$

The Lagrangian of this program is as follows:

$$L(\ ) = NU\left(c, \mathrm{P}, d, \mathrm{P}\right) + \lambda_1\left\{F\left(K, N\overline{p}, N\right) - Nc - Nd - K\right\} + \lambda_2\left\{R\left(P\right) - N\overline{p}\right\}$$

The resolution gives the following first order conditions with λ_1 and λ_2 designating the Lagrange multipliers.

- $\frac{\partial L(\ )}{\partial c} = 0 \Rightarrow \frac{\partial U}{\partial c} = \lambda_1$
- $\frac{\partial L(\ )}{\partial d} = 0 \Rightarrow \frac{\partial U}{\partial d} = \lambda_1$

$$\frac{\partial U}{\partial c} = \frac{\partial U}{\partial d} \Leftrightarrow U_{c^{**}} = U_{d^{**}} \quad \cdots\cdots\cdots(53)$$

$(**)$: refers to the optimal social solution.

- $\frac{\partial L(\ )}{\partial E} = 0 \Rightarrow \frac{\partial U}{\partial c} F_E = \lambda_2$
- $\frac{\partial L(\ )}{\partial P} = 0 \Rightarrow$

$$N\frac{\partial U}{\partial P} + F_E R'\left(P\right)\frac{\partial U}{\partial c} = 0 \quad \cdots\cdots\cdots(54)$$

- $\frac{\partial L(\ )}{\partial K} = 0 \Rightarrow F_K = 1 \Rightarrow F_{K^{**}} = 1 \cdots\cdots(55)$

The optimal level of licenses distributed P**, is deduced from (54).

The optimal level of permits to be issued takes into account all the technological conditions of the economy. In fact, by comparing equations (52), (53) and (54) we have:

$$q^* = F_E\left(K, N\overline{p}, N\right) + \frac{U_P\left(d, N\overline{p}\right)}{U_d\left(d, N\overline{p}\right)}$$

$F_E R'\left(P\right)\frac{\partial U}{\partial c} + N\frac{\partial U}{\partial P} = 0$ with : $\frac{\partial U}{\partial c} = \frac{\partial U}{\partial d}$; one obtains:

$$F_E R'\left(P\right)\frac{\partial U}{\partial c} = -N\frac{\partial U}{\partial P} \Rightarrow -\frac{1}{N}F_E R'\left(P\right) = \frac{\partial U}{\partial P} \bigg/ \frac{\partial U}{\partial d}$$

$F_E + \frac{U_P\left(d, N\overline{p}\right)}{U_d\left(d, N\overline{p}\right)}$ becomes

$$F_E - \left(\frac{1}{N}F_E R'\left(P\right)\right) = F_E\left(1 - \frac{1}{N}R'\left(P\right)\right)$$

$$q^* = \left(1 - R'\left(P\right)\frac{1}{N}\right)F_E \quad \cdots\cdots\cdots(56)$$

q^* : sale price of permits to future generation to delay pollution;

$F_E = \phi^*$: sale price of permits directly to firms by retirees causing emissions of pollutants through the production process.

It can be seen that when $q^* \leq \phi^*$, economic actors will prefer to sell to firms rather than to the next generation. Therefore, their individually rational decisions will cause pollution which constitutes a nuisance and causes everyone suffer from the negative effect of pollution. There is also a need for a subsidy or fee to mitigate the consequences of uncooperative agent behavior. Finally, the individualization and transferability of pollution permits cannot be a substitute for other pollution management instruments. These results lead to the following conclusion.

4. Conclusion

The quality of the environment can be managed through regulatory or economic instruments. It is in this sense that the Polluter Pays Principle, an economic instrument, is prescribed. This principle does suffer from many limitations. A priori, the issuer will just pay without worrying about the volume of pollution it emits. To mitigate these shortcomings, these instruments, whether regulatory or economic, must be underpinned by other incentives in order to transmit a better quality of the environment to future generations. This article shows that the free distribution of emission permits to young people of a period with the possibility for them to opt for physical goods or the quality of the environment does not constitute a sufficient policy for an intergenerational altruism. This behavior is

DOI: https://doi.org/10.30564/jesr.v2i1.449

explained by the non-cooperation of actors making necessary incentives such as taxes or subsidies.

References

[1] Beaumais, O. and M. Chiroleu – Assouline (2002), Economie de l'environnement, Bréal, Paris.

[2] Bonnieux, F. ans B. Desaigues (1998), Economie et politiques de l'environnement, Paris, Dalloz.

[3] Buisson, G. and M. Barnley (2007), Les quotas individuels de pêche transférables, Bilan et perspectives pour une gestion durable des ressources, www.ecologie.gouv.fr/-collection-Etudes-et-synthèses, lue le 20 novembre 2013.

[4] Bürgenmeier, B. (2010), Politiques économiques du développement durable, De Boeck.

[5] Chanel O., E. Faugere, G. Geniaux, R. Kast, S. Luchini and P. Scapecchi (2 004), « Valorisation économique des effets de la pollution atmosphérique » Revue économique, vol. 55, n°1, 65 – 92.

[6] Dales, J.H. (1968), Pollution property and price, Toronto University Press.

[7] De Perthuis C. et J-C. Boccon-Gibord, (2006), Le marché européen des quotas de CO2 : leçons d'un an de fonctionnement, Revue d'économie financière n°83, 115-132.

[8] Fodha, M. (2009), Protection mixte de l'environnement et externalités intergénérationnelles, Revue économique (3), vol.60, 843-852.

[9] Godard, O. (1995), Théorie et pratique de la mise en œuvre du principe pollueur payeur ; aspects économiques, sociologiques, institutionnels et politiques, Rapport au ministère de l'environnement.

[10] Hanoteau, J. (2004) « Lobbying pour les permis négociables et non – neutralité du mode d'allocation », Revue économique 55 (3), 517-525.

[11] Hardin, G. (1968), «The tragedy of the commons», Science, 162, 1243-1248.

[12] John, A., R. Pecchenino, D. Schimmelpfennig, and S. Schreft (1995), Short-lived agents and the long-lived environment, Journal of public economics, vol. 58, 127-141.

[13] John, A. and R. Pecchenino (1994), An overlapping generations model of growth and the environment, The economic journal, vol. 104, n°427, 1393 – 1410.

[14] Jouvet, P.A. et G. Rotillon (2005), Ressources renouvelables et quotas d'exploitation dans un modèle à générations imbriquées, Recherches économiques de Louvain, 71(1), 117-130.

[15] Kollmus, A. and M. Lazarus, (2010), Buying and cancelling allowances as an alternative to offsets for the voluntary market: a preliminary review of issues and options, OECD Publishing.

[16] Mahé, L-P. et C. Ropars (2001), L'exploitation d'une ressource renouvelable : inefficacité d'un rationnement factoriel et efficacité des Quotas Individuels Transférables, Economie et Prévision, n°148, 2001-2, 141 -156.

[17] Mekni, M.M. (2014), La participation des citoyens au marché de permis d'émissions, Thèse de Doctorat de Sciences Economiques, Université de Bordeaux.

[18] Michel, P. (1990), Some clarifications on the transversality condition, 58, 705-723.

[19] Michel, Ph., E Thibault, and J-P Vidal (2004), Intergenerational altruism and neoclassical growth models, Working paper series, # 386, European Central Bank.

[20] Prieur, F. (2006), Croissance et environnement dans le modèle à générations imbriquées : analyse dynamique et évaluation de politiques publiques, Thèse de Doctorat de l'Université Aix-Marseille II, Sciences Economiques.

[21] Prieur, M. (2001), Droit de l'environnement, Paris, Dalloz.

[22] Schwartz, S. (2009), Comment distribuer les quotas de pollution? Revue d'économie politique, 119(4), 535-568.

[23] Svendsen, G.T. (1999), The idea of global CO2 trade, European Environment, 9, 232 -237.

[24] Vallée, A. (2002), Economie de l'environnement, Editions du Seuil.

[25] Zhang, J. (1999), Environmental sustainability, nonlinear dynamics and chaos, Economic theory, 14, 489-500.

  DOI: https://doi.org/10.30564/jesr.v2i1.449