Tradable emission permits, environmental maintenance and applied overlapping generations general equilibrium model

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- Preliminary version -

Abstract :

This paper displays in the scope of an overlapping general equilibrium model simulated in dimension 3 (Capital, Labours and Environment).

The first part of the model represent an economy in which households have a classical work revenues allocation behaviour (consumption, saving, payment of taxes); Public Authority without environmental policy, finances retirement; and pollution with harmfull effects on the society, are produce by firms activities.

In the second part, an environmental policy to fight aigainst pollution is introduced throught a tradable emission permits system coupled to a tax system which finances environmental maintenance. Here, properties rights on environment are defined, owned by youngs generations, and maintenance activities produce positives intergenerational welfare effects.

Then, an applied model calibrated on French economy social accounting matrix 2004, called 'MEGGI 2-3', is build with Fortran and GAMS, and some steady state carateristics are studied.

Keys words :
Tradable emission permits, Environmental maintenance, pollution, Applied general equilibrium, Overlapping generations models.

JEL Codes : D62, D91, Q50, C68.

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1. Introduction

For a decade, international mobilization (Kyoto Protocol (1997), Bali Conference (2007)), around problems concerning climatic changes is increasin more and more and, has succeeded in the introduction of quantitives constraints as a means of fighting against global warming. These constraints are expressed in reality by the setting up of a system of tradable emission permits, which allow definition of properties rigths on the environment. Indeed, in the presence of externalities, economic theory proposes as solution of internalization and/or realization of social optimum in a market economy (Coase [1960]), the definition of property rights, in the case of their absence prior.

Since the Kyoto protocol [1997], most of industrialised countries engaged themselves to reduce their emission of greenhouse gases (GHG) during the period 2008-2012, of about 5% of 1990's reference level. The European-Union (EU) – of which France – decided to apply this constraint to industrial sectors defined in the appendix of the protocol, putting off the threshold at 8%.

Concerning the choice of the instrument used, as underlined by Jouvet & al. [2002], the advantage of a tradable emission permits system comes from the fact that they intervene ex-ante on the environment and allow the fixation of a quantity of emission leaving prices to adjust themselves; then, tradable permits offer a great flexibility in terms of adaptation to changes in market structure or to the modification of environmental macroeconomics.

The question of environmental policies aiming at mitigating against GHG effects such as global warming is the subject of an increasing particular attention for some years. The application of these policies with the help of tradable permits through the setting up of a related market raises number of difficulties on the initial allocation of tradable permits, on their macroeconomic consequences (Jouvet & al [2002]).

Beyond, because of long term GHG effects, as underlined by Rasmussen [2003], *'environmental policies are considered as a very long time frame, which naturally raises the question of intergenerational equity'*. This assumes the use of adapted instruments such as applied overlapping general equilibrium models, to evaluate long term macroeconomics impacts of the introduction of tradables emission permits in an economy system. Here in this paper, our application is on the French economy.

However, OLG models constitute an analytical frame enabling an alternative mode of representation of agents behaviour, characterised by life cycle realities ; it's also a theoritical frame of growth dynamic/intertemporal models writings, which studying intergenerational revenue distribution questions. As Shillings [1995] underlined, *'using Infinite Life Agent model with environmental problems, involves a fallacy of composition on the intergenerational fairness. Consequently, abatement policies should be seen in the context of decisions involving intergeneration redistribution rather than intertemporal saving'*.

Unlike the usual frame of infinity live cycle agent' (Ramsey [1928]) where a representative agent maximises an intertemporal utility, in OLG model frame, demographic realities concerning life cycle are taken into account. Therefor, we consider a representative agent with a finite life cycle - because he lives for two periods in the model – in an essential framework of dynamic optimization discrete-time.

In order to evaluate the mentioned effects above, both side computational overlapping generations model with GAMS[1], calibrated on the 2004 social accounting matrix describing the French is proposed. The paper focuses on the impacts of introducing tradable emission permits system in an economy initially devoid of environmental policy goals, under general equilibrium framework.

This paper is organized as follow:

Section 2 presents the economy initially without any environmental policy goal, in which the public authority carries out a usual economic policy objectives (financing of public goods, pension funding). The situation is qualified as "Business As Usual (BAU)" and we obtain a stationary numerical solution after building the model called "MEGGI-2" with GAMS.

In section 3, an environmental policy is introduced in the economy, through implementation of a tradables emission permits system. Property rights are then defined on the environment and are assigned to youngs generations in the model. The initial model (MEGGI-2) is thus modified and modified into a three factors (Capital, Labour, Environment) computational model called "MEGGI-3".

General equilibrium of the twice models is characterized in section 4. Computationals approaches are briefly presented in section 5 and the next section (6) deals with analyses around MEGGI-3 steady state. The last section concludes, whereas an appendix presents data base and the parameters used for the calibration.

2. Business As Usual framework[2]

a. Generalities

We suppose a Diamond' [1965] OLG model where an aggregate consumption and investment goods is produced. Firms activities generate environmental pollution which has a negative impact on agents utility. In this first part, Public Authority doest not regulate the negative external effect, which is source of desutility for individuals in the economy.

b. Household behaviour

i. Basic hypothesis

Agents are assumed to have a finite life span on two periods[3] and have perfect foresight. In the first period, they are referred to as the young (active period, named t), and old in the second period (retirement period, named $t+1$) $\left(H_1\right)$[4]. A same number of agents denoted $\left(N_t=1\right)$ is born in every period t, and supplies one unit of labor inelastically to the labour

[1] General Algebreaic Modeling System.

[2] Here in BAU, to simplify equations writing, we suppose that variables and parameters have this notation : $\forall x, \forall \varepsilon$ consider x_t^{BAU} , ε_t^{BAU} .

[3] Cf. Diamond's 1958 model, p.449, in Truman F. Bewley 2007 General Equilibrium, Overlapping Generations Models and Optimal Growth Theory, Harvard university Press, Cambridge ou voir Schubert [2000],pp. 270-285.

[4] $\left(H_i\right)$ for Assumption *i.*

market $\left(L_t\right)$ and receives a wage w_t. Then, we assumed that the active population is only consituted of youths. Wages are used when young for consumption c_t and saving $\left(H_2\right)$ (see $\left[Eq_1\right]$ below) ; during retirement, agent lives off his capital (net returns from the accumulation of savings during the activity period) and transfers received from the Public Authority $\left(H_3\right)$ to finance his consumption b_{t+1} $\left[Eq_2\right]$. We also assume in the model (also useful for simulations) that, at time 0, there is an old generation borned at t-1 with an exogenous capital $K_0 > 0$. We are also assumed agents' incomes (wages, returns from saving, transfers) are taxed $\left(H_4\right)$ by Public Authority, to finance transfers to old ($TRF_t = Tau_t.w_t$) and public goods $\left(\lambda_t\right)$.

The described relations are recapitulated in the maximization program below :

$$\begin{cases} \underset{c_t, c_{t+1}}{Max}\left\{U\left(c_t, c_{t+1}\right)\right\} \\ c_t + s_t = w_t\left(1-\lambda_t\right)\left(1-Tau_t\right) & [1] \\ b_{t+1} = \left[1+r_{t+1}\left(1-\lambda_{t+1}\right)\right]s_t + TRF_{t+1}\left(1-\lambda_{t+1}\right) & [2] \end{cases}$$

In the model as well as in the simulations, a fixed parameter (time preference rate[5]) is introduced into the functional form the utility expression.

ii. Intertemporal optimisation

This optimisation problem under constraint in the framework of overlapping generations model is resolved through the construction of the Intertemporal Budget Constraint (IBC) relation. In the BAU, we have specified a logarithmc utility function :

$$U(c_t, c_{t+1}) = \log c_t + Phi.\log b_{t+1} \quad [3]$$

From then, the IBC is :

$$c_t + \frac{b_{t+1}}{\left[1+r_{t+1}\left(1-\lambda_{t+1}\right)\right]} = w_t\left(1-\lambda_t\right)\left(1-Tau_t\right) + \frac{TRF_{t+1}\left(1-\lambda_{t+1}\right)}{\left[1+r_{t+1}\left(1-\lambda_{t+1}\right)\right]} \quad [4]$$

Where :

- TRF_{t+1} : Transfers received when old ;
- $TRF_t = Tau_t.w_t$.
- r_{t+1} : Interest rate between periods t and $t+1$, on the capital market.

[5] Which express the degree of impatience of the representative households to consume.

iii. Optimal consumption

By placing the following expression as being the 'discounted life cycle income' (RCV) :

$$RiCVi_t = w_t(1-\lambda_t)(1-Tau_t) + \frac{TRF_{t+1}(1-\lambda_{t+1})}{[1+r_{t+1}(1-\lambda_{t+1})]} \quad [5]$$

First and second periods optimal consumptions are established as follow :

$$c_t^{BAU} = RiCVi_t\left(\frac{1}{1+Phi}\right) \quad [6]$$

$$b_{t+1}^{BAU} = \varphi.c_t^{BAU}.[1+r_{t+1}(1-\lambda_{t+1})] \quad [7]$$

Relation $[7]$ which is expressed in terms of optimal consumption of the first period is the 'Euler's Intertemporal Equation'. Because all accumulated savings in the first period is used, this last equation shows the absence of bequest. Knowing that $N_t = N_{t-1}$, and that aggregate consumption[6] $\left(C_t^{BAU} = N_t c_t^t + N_{t-1} b_t^{t-1}\right)$ is the sum of both generations at each current period, we have :

$$C_t^{BAU} = N_t RiCVi_t\left(\frac{1}{1+\varphi}\right) + N_t\left(\frac{\varphi}{1+\varphi}\right)RiCVi_t[1+r_{t+1}(1-\lambda_{t+1})] \quad [8]$$

Rewriting as follow :

$$C_t^{BAU} = \frac{N_t RiCVi_t}{(1+\varphi)}\left(1+\varphi[1+r_{t+1}(1-\lambda_{t+1})]\right) \quad [8bis]$$

c. Enterprises

i. Production

Production (Y_t) of an aggregate goods is done by firms which exploit a Constant Returns to Scale (CRS) Cobb-Douglas technology $Y_t^{BAU} = A_t K_t^{\alpha} L_t^{1-\alpha}$ $[10]$. So, assuming perfect competition assumptions, each firm choose K_t, L_t to maximize profits $\pi_t^{BAU} = A_t K_t^{\alpha} L_t^{1-\alpha} - \left(wL_t + (r_t+\delta)K\right)_t$ $[11]$, by equalizing the marginal productivity of factors production process, at their real cost.

[6] Total consumption is called 'aggregate consumption' and C_t^{BAU} .

ii. Necessary Optimality Conditions

Given decision variables K_t, L_t :

$$\left\{\underset{K_t,L_t}{Max}\left\{\pi_t^{BAU}\right\}\right. \quad et \quad \begin{cases} \partial\pi_t^{BAU} / \partial X_i = 0 \\ X_{i,t} = K, L \end{cases} \quad \text{CNO :} \Rightarrow \quad \begin{cases} r_t^{BAU} = A_t \alpha K_t^{\alpha-1} L_t^{1-\alpha} - \delta & [12] \\ w_t^{BAU} = (1-\alpha)\dfrac{Y_t^{BAU}}{L_t} & [13] \end{cases}$$

With :

- α : Share of capital in production ;
- δ : capital depreciation rate ;
- π_t : Firm's profit

iii. Investment equation

Capital accumulation is characterized by the following investment relation :

$$I_t^{BAU} = K_{t+1} - (1-\delta) K_t \qquad [14]$$

d. Public Authority/Government

i. Government Budget and Public Expenditures

Public spendings and retirement (income redistribution) are funded by taxes. At time t, PA expenditures (GP_t) are given by this above relation :

$$GP_t^{BAU} = \lambda_t N_t w_t \left(1 - Tau_t\right) + N \lambda_t r_t s_{t-1} + \lambda_t N.TRF_t \qquad [15]$$

ii. Public Authority retirement fund

Retirement budget which is used to finance transfers to old generations, comes from tax on young generations gross wage :

$TRF_t^{BAU} N_{t-1} = p_t w_t L_t \;\Rightarrow\; TRF._t^{BAU} N_t = p_t w_t L_t \;\Rightarrow\; TRF_t^{BAU}.N_t = p_t w_t N_t \;\; [15]$ since $N_t = L_t$.

3. MEGGI-3 : Overlapping Generations with environmental policies through tradable emission permits and maintenance

a. Introduction and environmental policy instrument

Firms production activities GHG are contributiong to global warming by adding heat-trapping gases to the atmosphere, and thus degrades the environment which is consider in the model as a 'public good'. We assume that firms have the same technology, and fossil fuel use is the main source of these gases. Finally, a last assumption is made here : Our Government (Public Authority) is a Supranational Committee (SC) member. Following an international mobilization (e.g : Kyoto Protocol), the SC has decided the adoption of binding quantitative emissions reductions targets, through the implementation of an environmental policy instrument. So, Public Authority applied and controlled in the national economy, a system af tradable emission permits (H_5).

Tradables permits initial allocation

Here, property rights are defined on the environment. Indeed, we assume that these rights are owned only by households and purchased from PA, can therefore be resold by them, on an organized tradable emission permits market (H_6). At each period, property rights transferred by the government to households at price p_t generate an amount $p_t e_t$ is exactly equal to an exogenous quota initially set by the SC during emissions reductions targets decision-making.

How firms get tradable emissions permits ?

H_8.

We assume that households resell tradable emission permits to firms at price q_t, and that the sale price is greater than its acquisition price $(q_t > p_t)$ to Public Authority, thus $\frac{q_t}{p_t} > 1$. This assumption allow to define the existence of a tax $(\xi_t \in]0,1[)$ applied on the added value $\{d_t = (q_t - p_t)e_t\}$ realized by households following their sales of emissions permits to firms, which need them for production activities.

H_9.

i. Tax amount $(\xi_t d_t e_t)$ and the initial value of property rights $(p_t e_t)$ constitute the Government budget (GP_t^{ME}) which is allocated to maintenance of the environment (carbon sink [7] by enhancing natural and artificial carbon sequestration through reforestation for example).

ii. If $\frac{q_t}{p_t} \equiv 1$, tax amount is (almost) null $(\xi_t d_t e_t \equiv 0)$, and Public Authority in this case does not realize any environmental maintenance activity $(GP_t = GP_t^{BAU})$ (see equation 15).

[7] This concept has become more widely known because the Kyoto Protocol allow the use of carbon sink as a form of carbon offset. Ths concept is based on natural ability of trees, to suck up carbon dioxide and store it in woods and leaves.

Proposition 1

Operations financed in the frame of this environmental maintenance would generate benefic effects ; we qualify them as 'welfare intergenerational positive effects'.

b. Firms and GHG emissions dynamics

i. The dimension 3 production function

Firms renting environment to households assure at each period, production of an aggregate goods, due to a neoclassical production technology with constant returns to scale. However, by the employment of three 'intrants' : capital (K), (L) and tradable emissions permits – representing demand environment factor -(E) (H_{10}). At each period t, production in the economy Y is represented by a Cobb-Douglas : $Y_t^{WE} = A_t K_t^{\alpha} L_t^{\beta} E_t^{\gamma} \quad [16]$ where $\alpha + \beta + \gamma = 1$.

ii. Firms objectives

In this frame, the representative firm maximizes a profit function according to this following relation :

$$\pi_t^{WE} = A_t K_t^{\alpha} L_t^{\beta} E_t^{\gamma} - \left(wL_t + \left(r_t + \delta \right) K_t + q_t E_t \right) \quad [17]$$

From this relation, is gotten modified relations of marginal productivity of the factors bellow :

$$\partial \pi_t^{WE} / \partial x_i = 0 \quad où \quad i = (L, K, E) \Leftrightarrow \begin{cases} w_t^{WE} = \beta . Y_t^{WE} / N_t & [18] \\ r_t^{WE} = \alpha . A_t K_t^{\alpha - 1} N_t^{\beta} E_t^{\gamma} & [19] \\ q_t = \gamma . A_t K_t^{\alpha} N_t^{\beta} E_t^{\gamma - 1} & [20] \end{cases}$$

iii. Investment equation

Capital accumulation equation is the same as seen in equation 14 :

$$I_t = K_{t+1} - (1 - \delta) K_t \qquad [14bis]$$

iv. Emissions dynamics and pollution accumulation

At each period t, firms in a competitive market are allowed to emit as must pollution as it has acquiry the rights to emit, either by owning it on the tradable emissions market where households are sellers. Pollution is generate by the use of emissions permits in firms activities, and has negatives impacts on the environmental quality. Hence the negative correlation between tradable permits and quality of environment. As found in Jouvet & al [2002], *'pollution stock at a particular time t depends on the stock of pollution of preceding period –*

and of the demand of tradable emission permits revealed by firms – during the current period'.

Noting ψ the rate of natural absorption of pollution, we assume that the global stock of pollution follows the dynamics below :

$$P_t^{ol} = E_t + (1-\psi)\, P_{t-1}^{ol}$$

Where E_t represent GHG emissions during the period, which is equal to the fixed initial national quota.

c. Behaviour of other institutional model components

i. Households : Generalities

General characteristics concerning life cycle remain the same to those described in *§2.b.i.*

Proposition 2

The introduction of tradable emission permits in the economy and the definition of property rights on the environment change the allocation of household income.

Indeed, here, households' wages is used for the consumption c_t, saving as well as for owning of property rights on the environment pe_t from Public Authority. In the retirement old agent consumption b_{t+1}, is finance with the accumulated net returns from saving, during the period of actitivity and net transfer received from the Government. This program below caracterises the behaviour of households.

Optimization program

The representative consumer of a generation maximizes his preferences which are expressed across the intertemporal utility fonction below. This relation is written by the help of consumption of the two periods, and also of a parameter (ψ) that we introduce and which reflects the quality of environment during the periods of life cycle ; thus, translating the fact that each agent at both life periods, is sensitive to his consumption conditions.

$$\begin{cases} \underset{c_t, c_{t+1}}{Max}\left\{U\left(c_t, Q_t, b_{t+1}, Q_{t+1}\right) = U\left(c, \psi\right)\right\} \quad où \quad \psi = f\left(Q_i\right), \quad \forall i \in \{t, t+1\} \\ w_t\left(1-\lambda_t\right)\left(1-Tau_t\right) + \left(q_t - p_t\right) e_t (1-\xi_t) = c_t + s_t \qquad [22] \\ b_{t+1} = \left[1 + r_{t+1}\left(1-\lambda_{t+1}\right)\right] s_t + TRF_{t+1}\left(1-\lambda_{t+1}\right) \qquad [23] \end{cases}$$

The function specified below express the utility of agents :

$$\begin{cases} U\left(c_t, b_{t+1}, \psi\right) = U\left(c_t, \psi\right) + \left(\dfrac{1}{1+\varphi}\right) U\left(b_{t+1}, \psi\right) \qquad [24] \\ U\left(x, \psi\right) = \left(\dfrac{1}{1-\theta}\right) \psi . x^{\theta} \qquad x = \{c, b\} \end{cases}$$

Where:

- θ represents the elasticity of intertemporal substitution $\left(\frac{1}{\sigma}\right)$ with $(\sigma \neq 1)$;
- φ is the time preference rate $(\varphi \in [0,1])$.

Optimal consumption

With the constraints $[22]$ and $[23]$, the following results are obtained :

$$\partial U / \partial x = 0 \Leftrightarrow \begin{cases} c_t = \left\langle RiCVi_t \left[1 - \frac{\left\{ \frac{1+\varphi}{\left[1+r_{t+1}(1-\lambda_{t+1})\right]} \right\}}{1+\left[1+r_{t+1}(1-\lambda_{t+1})\right]} \right] \right\rangle & [25] \\ b_{t+1} = \left\langle \frac{RiCVi_t \left[\frac{1+\varphi}{1+r_{t+1}(1-\lambda_{t+1})} \right]^{1/\theta} \left[1+r_{t+1}(1-\lambda_{t+1})\right]}{1+\left[1+r_{t+1}(1-\lambda_{t+1})\right]} \right\rangle & [26] \end{cases}$$

Where:

$$RiCVi_t^{WE} = d_t e_t (1-\xi_t) + w_t (1-\lambda_t)(1-Tau_t) + \frac{TRF_{t+1}(1-\lambda_{t+1})}{\left[1+r_{t+1}(1-\lambda_{t+1})\right]} \quad [27]$$

Total agent consumption in period t is:

$$C_t^{WE} = N_t . c_t^{WE} + N_{t-1} b_t^{(t-1)WE} \quad [28]$$

ii. Government' budget

Under the assumption of a tax financing environmental maintenance, the initial budget of the Public Authority becomes :

$$GP_t^{WE} = GP_t^{ME} + GP_t^{BAU} \quad [29] \quad Avec \;\; GP_t^{ME} = N_t p_t e_t + N_t \xi_t d_t e_t$$

Environmental maintenance

Environmental maintenance operations setting by Public Authority during each period has a direct effect on the parameter (ψ), which increases or decreases the utility of agents. When this maintenance is realised at an optimal level, due to cumulative positive effects, environmental quality is better during the current and next period $t+1$ (intergenerational positive effect).

Proposition 3

The optimal tax is that which helps the economy to respect the quota of GHG emissions fixed endogenously by the suppranational committee such that all the optimum relations presented above hold.

4. General equilibrium

The following relations are applied on the two parts of the model developpped in the two preceding sections, with the exception of the fourth market below which concerns only section 3.

Labor Market

The active population is equal to the number of agents of the generation, which gets into the model at the beginning of period t; we find again the equality $N_t = L_t$ at each period, on the labour market.

Capital market

We assume as in Schubert [2000], that at the initial period of the economy or preceding the current period t, there is an initial saving (S_{-1}) which helps to finance an initial stock of capital (K_0) ; and generally as it follows, that savings of youths finances the stok of capital such that at each period t, we could obtain the equilibrium relation $K_{t+1} = S_t \quad [30]$.

Market of goods and services

The demand – supply equilibrium on the market of goods in each part of the model exposed is :

$$\begin{cases} Y_t^{BAU} = C_t^{BAU} + I_t^{BAU} + GP_t^{BAU} & [31] \\ et & \\ Y_t^{WE} = C_t^{WE} + I_t^{WE} + GP_t^{WE} & [32] \end{cases}$$

Market of tradable emissions permits

We apply here the Walras' law principle in general equilibrium theory that states, 'if all but one of the markete are in equilibrium, then the remaining market is also in equilibrium, automatically'. Thus, we consider that the equilibrium on the tradable emission permits market is realised.

The simulation of MEGGI-3 helps to established that the model has one optimal solution ; so, there atleast one equilibrium point (stable or unstable, 'interior' solution or not). The section below deals with these aspects of which answer are gotten from characteristics established by analyses around overlapping generation model steady state.

5. Macroeconomic approach : Economic agents, data base, method and computational solution

In this analytical frame, agents behaviours as described below, leads to exchanges in the economy that we have reproduced in a social accounting matrix, calibrated following the specific approach of general equilibrium overlapping generation model. Data used are French economy 2004 national accounting data.

a. A computational aspect : Calibration

This essential step consist of changing value of model input parameters in oder to reproduce a reference or initial general equilibrium situation on the defined periods. In the framework of a dynamic model, this general equilibrium found by the resolution of optimization program, and which is spreaded out on several periods is qualified as 'steady state equilibrium'.

b. MEGGI-3 Calibration steps summarizing

This operation is realised in the applied model constituted of :

- Giving an initial value to $r_t + \delta$, w_t and different taxes introduced ;
- Determining the level of transfers then, the initial value of optimum consumption of the first period, which helps to determine the consumption of following periods and aggregate demand ;
- 'Blocking' the model, such that it reproduces the values of parameters initially fixed.

6. Some analyses around MEGGI-3 steady state

a. Generalities

By stating the relation of capital accumulation within the economy, it is possible to express it in terms of variables and parameters on which depends the saving function ; that is relative prices, tax on profit resulting from the sale of tradables emission permits, and the stock of pollution.

According to $[30]$ $K_{t+1} = N_t s_t$.

Consider ν_t total saving of an agent, such that :

$$\nu_t = \nu\left(F_L(K,1,e), F_K(K,1,e), F_e(K,1,e), P_{t-1}^{ol}, P_t^{ol}, e_t, p_t, \xi_t\right) = s_t - d_t e_t(1-\xi_t) \quad [33]$$

Thus, $K_{t+1} = \nu_t + d_t(1-\xi_t) \quad [34]$.

At all steady state, we have the following steady capital and pollution equations :

$$\begin{cases} [35] \quad K = \nu(w,r,q,P,P,e,p,\xi) + d(1-\xi)e \\ [36] \quad P^{ol} = \dfrac{e}{\psi} \end{cases}$$

Such that the relation :

$$K\left(1 - d(1-\xi)\frac{e}{K}\right) = \nu\left(w(K,1,e), r(K,1,e), q(K,1,e), \frac{e}{\psi}, \frac{e}{\psi}, e, p, \xi\right) \quad [37]$$

The general form characterising approximately the steady state of Diamond's model, helps obtain a level of capital stock liable to being the solution to the equation above.

b. Steady state characterization

We determine this following relation:

$$\left(1 - d(1-\xi)\frac{e}{K}\right) = \frac{\nu\left(w(K,1,e), r(K,1,e), q(K,1,e), \frac{e}{\psi}, \frac{e}{\psi}, e, p, \xi\right)}{K} \quad [38]$$

Galor & Ryder [1989] (See De La Croix & Michel [2002], Jouvet & al. [2002] or Jouvet & Prieur [2006]) shows as sufficient condition in the frame of overlapping generation models that there exist an 'interior' steady state' if :

$$\lim_{K \to 0} \frac{\nu(\cdot)}{K} > 1 \quad [39]$$

Verification

According to the parameters fixed that help to obtain the computational solution, we establish that :

$$\begin{cases} d(1-\xi_t) > 0 \\ Si \quad K \to 0, \; -\dfrac{e}{K} \to -\infty \quad 1 - \left(d(1-\xi_t)\dfrac{e}{K}\right) \to -\infty \end{cases}$$

This last result shows that with MEGGI-3 assumptions, from the steady state obtained in the model with environment, Galor & al. assumptions are not verified in the case of tradable emissions permits owned by young's generations.

7. Conclusion

In the framework of an applied study, we have built an overlapping generations general equilibrium model with two parts. The first, without any environmental policy targets in the presence of a negative externality; an then, the introduction of a tradable emissions permits system. An initial rule of allocation is specified in the model; then, we have assumed a tax system financing environmental maintenance, and which generate positives intergenerational welfare effects on future generations.

8. References

Beaumais O., Chiroleu-Assouline M., [2002], *Économie de l'environnement*, Bréal, Collection « Amphi ».
Beaumais, O. [2005], **'**Viok, a Simple OLG, note technique', CARE, avril.
Brooke, Kendrick & Meeraus [1992], 'GAMS user's guide' (www.gams.com).

Diamond P.A (1965), "National Debt in a Neoclassical Growth Modle", American Economic Review, vol 30, pp. 657-740.
De la Croix D. et Michel Ph. [1999], "The overlapping Generations Approach to capital Accumulation", D.T, GREQAM.
Directive Européenne 2003/87/CE
Galor O. et ryder H.E (1989), "Existence, Uniqueness, and Stability of equilibrium in an Overlapping Generations Model with productive capital", Journal of economic theory, vol 49, pp. 360-375.
Jouvet, P-A., Prieur, F. [2006], Permis de pollution et contraintes politiques dans un modèle à générations imbriquées, Document de travail – Economix.
Jouvet, P-A., Michel, P., Vidal, J-P. [2002] Effets des permis de pollution sur l'accumulation du capital dans le cadre des modèles à générations imbriquées, Economie et Prévision n° 156, pp. 63-72, La Documentation française.
Obstfeld, M., Kenneth, R. [1997], Foundations of international macroeconomics, The MIT Press, 2ème edition, Cambridge.
Protocole de Kyoto [1997]
Schubert, K. [2000], Macroéconomie, Comportements et croissance, Vuibert 2ème édition.
Truman F. Bewley. [2007] General Equilibrium, Overlapping Generations Models and Optimal Growth Theory, Harvard University Press, Cambridge.

a. Parameters and Variables of MEGGI-3, model with environnemental policy targets[8]

MEGGI-3 Calibrate Parameters	
N(t)	*1.000000000*
Alpha	*0.277916477*
Beta	*0.661219549*
Omega	*0.060863973*
S0 (Initial Saving)	*367.350000000*
TD	*0.749993192*
P(t)	*0.441000000*
d(t)	*0.559000000*
Tau(t) -	*0.150000000*
Lambda(t)	*0.200000000*
Ksi(t)	*0.150000000*
Teta(t)	*0.100000000*
Gamma(t)	*2.000000000*
A(t)	*196.024273300*
Phi(t)	*0.510813209*

MEGGI-3 Variables	
Y(t)	*1321.800000000*
K(t)	*367.350000000*
E(t)	*80.450000000*
r(t)	*0.250006805*
w(t)	*874.000000000*
q(t)	*1.000000000*
C(t)	*810.897817200*
c1(t)	*265.195818200*
c2(t)	*545.701999900*
GP(t)	*235.392182600*
I(t)	*275.510000200*
RCV(t)	*719.945421700*
TRF(t)	*131.100000000*
S(t)	*367.350000000*

[8] Please, GAMS codes available on request.