TRADABLE EMISSION PERMITS AND GENERAL EQUILIBRIUM THROUGH APPLIED OLG MODELS: A SURVEY

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Received April 10, 2007 Accepted June 23, 2007

ABSTRACT

The paper describes and summarises the literature on applied general equilibrium models. Furthermore, it focuses on Overlapping Generations (OLG) models applied to environmental problems and it studies some recent papers on tradable emission permits in view to analyse economic impacts of those permits on greenhouse gas phenomena and/or climate change.

Key Words: General equilibrium, Overlapping generations, Tradable emission permits, OLG models

INTRODUCTION

Environmental problems in general and atmospheric pollution in particular are characterised by economic analysis as negative externalities coming from consumption and production. The standard theory applicable to this type of specific problem proposes their internalisation either by imposing a tax on pollution emitted or the installation of market for pollution rights where they are faulty.

On one side, agents whose life horizon is finite do not take into consideration long term consequences or repercussion of their polluting activities on the environment. It goes without saying as précised by Germain et al1. That “decisions (or absence of decisions) on these questions are likely to affect environmental quality today, but equally in the future.” On the other hand, externality theory does not propose any direct solutions to the intergenerational aspect of the repercussions of these environmental problems.

According to Howarth cited by Fodha2, such intrinsic problems, difficult to analyse and their existence modifies certainly socially desirable policies all together. During the 1990’s, environmental problems are perceived on the global scale, presenting negative effects and consisting of economic consequences for future generations. Climatic changes and irreversible effects of the degradation of biodiversity have the common characteristic of complicating economic analyses the more in the theoretical perspective of wellbeing3, cited by Howarth and Norgaard. Given the dynamics and complexities of environmental systems, actual pollutions let foresee unpredictable potential costs on future generations. However, the dialectic which permits environmental economists set aside questions on intergenerational equity leave essential questions unsolved.

Certain numbers of economists support that questions on sustainable
development are solved under the “cost-benefit” analyses. According to this concept, institutions necessary for internalisation of environmental externalities, efficient management of ownership rights and the intertemporal allocation of resources would preserve sufficient resources for future generations.

Other sustain on the contrary that the efficient management of resources is insufficient to assure a sustainable development. In this light, techniques said to be ‘standard’ of evaluation should be completed by durable constraints so as to maintain the integrity of the system of natural resources. Implicit prices, on which the ‘cost-benefit’ approach is based, are nevertheless random on the initial allocation possessed by each agent. Howarth and Norgaard, affirm that the “cost-benefit” analysis is unadapted, because the discount rate is of endogenous nature, and depend on the intergenerational distribution of assets. Extensions coming from limits of this analysis so result on an intergenerational approach of resource allocation.

Need to be notice that studies on intertemporal allocation are often handicapped by hypotheses that reject realities on human demography. In effect, in environmental economics, studies lined up in the standard theory framework, and in this line, admitting that the life span of individuals correspond to that of the economy, considering the hypothesis of agents with infinite life span following Ramsey, have for many, been restrained to analysis of intragenerational externalities. However, it appears that the environment presents characteristics of a public good for which decisions taken today condition the environment quality enjoyed by present generations together and those to come, as well as their wellbeing.

According to Howarth and Norgaard, agents with an infinite life span model usage does not permit to enlighten the relationship between intergenerational equity and efficient allocation in an intertemporal competitive economy.

The present note’s objective on one hand is to describe and place modelling in general equilibrium, applied to the environment in literature, through particular considerations. It also proposes an explanation for remedy to models with overlapping generations (OLG), and reviews some models amongs principals.

The paper is organised as follow: next to the introductive first section, the second section comes back briefly on the general equilibrium concept, then general equilibrium modelling applied to the analysis of environmental problems in particular; a third section exposes a few historical elements on applied models as well as their interest. The next two sections tackle the different classes of CGE models identified in literature and a global view on the type and structure of applied models on environmental policies. Next, section 6 stresses the particular case of OLG models, and deals with models that use tradable emission permits; then, the last section concludes.

**General equilibrium and applied modelling to environmental problems**

The general equilibrium model is with no doubt the most complete of economic theory. Someone paradoxically, it is a macroeconomic model, since it has as vocation to talk about an economy as a whole, meanwhile it can be considered as the culmination point of the microeconomic approach.

The theory of general equilibrium studies - in function of the form of social organisation that preside over relationship of agents – and supplies important signals concerning the factors and mechanisms that determine relative prices ; it equally proposes a study on the allocation mechanism of scarce resources by the market, but equally between markets.

An important question may be for example to know what will become of an
economy composed of numerous selfish individuals, so only in their individual interest, the neoclassic economist would propose a response which gives the possibility of defining the subject of the general equilibrium model analysis.

In deed, if we come back to the idea behind the thought of Smith\(^7\), Arrow and Hahn\(^8\) presenting a global view of the overhang of the general equilibrium theory; as a response to the preceding question, they propose the following: “a decentralised economy, where each individual acts in his personal interest in function of price signals, permits a distribution of disposable resources that can be looked at as preferable, in a definite sense, to a class of alternatives. Furthermore, the price system operates in way to establish this coherence.”

Taking its origin from Walras’ works and based on neoclassical hypotheses, the general equilibrium is then completed by meticulous contribution of Debreu and Arrow. The underlying special feature is a modelling of the simple and fundamental observation that markets in reality are mutually interdependent.

Most contributions brought to the general equilibrium theory have in the past been focalised very often on the analysis of allocation mechanisms of private goods as well as private ownership of resources; contrary to this tendency, extraordinary works of Mäler in 1974, inspired from those of Ayres and Kneese\(^9\), extend the framework of general equilibrium to externalities and environmental resources having those characteristics of publics goods.

The start of 1990s coincides with the realization and international mobilization–UNFCCC–on environmental problems in general, and changes in climatic conditions in particular, liked to the emission of gases with greenhouse effects. With the fixation of restrictive quantitative objectives, Kyoto’s protocol\(^10\) is a starting point for countries that engaged themselves towards a process of fight for environment protection.

Economists not remaining out of such a process have reacted and participate actively by the elaboration of diverse contributions (construction of predictive models, simulation models, models for implementation of policies for the fight against climatic warm up). Back up by robust software such as GAMS (Brooke et al.\(^11\), Rutherford\(^12\), these models qualified for their apply characteristics, thus become an efficient tool often used for the analysis and comprehension of economic impacts for the fight against environmental pollution.

Depending for example on our interest for externalities that come from a process of production (use of fossil energy very pollution–so it is evident that there exists a strong link between their usage and the emission of greenhouse gases associated–and other behaviours of consumption causing pollution) or a management of sample resources (renewable and non renewable), we can distinguish applied models, said to be CGE, adapted to each case.

However, CGE models treating about externalities largely dominate in literature. Control mechanisms of transboundary externalities such as problems of atmospheric pollution received a particular attention in recent literature\(^13\).

These applied models to these specific problems have as goal to analyse from an economic point of view, consequences and different impacts (social and environmental) of the introduction of environmental tools for reduction of emissions – tradable emission permits – necessary for the protection of the environment, and in the fight against the additional greenhouse effect caused by atmospheric pollution of antropic nature.

**Historical and Interest of CGE models**

Few historical elements on applied modelling and their interest in response to environmental problems

Applied modelling in general equilibrium expressed across CGE models has
known as crescent gain of interest. It was developed from three separate original contributions, namely, the works of Johansen, Scarf and Jorgenson, to whom writings attribute the origin of applied models of general equilibrium.

This applied form characterised by the construction of models is an operational means of use of the theoretical corpus of general equilibrium to study new questions and preoccupations; this taking into consideration the emergence of new complex problems (pollution, climate changes) faced by the entire society as a whole, and which requires particular attention of economists.

The various definitions below, from three different sources express clearly what CGE models are according to Peterson:

Bolnick, “A CGE model is ‘computable’ in that an explicit numerical solution is computed. Values for all endogenous variables in the model are calculated from equations describing the economy, given numerical values for the parameters and the exogenous variables (such as policy variables and the initial capital stock). CGE model are simulations models”.

According to Markusen, “CGE modelling is a way around the difficulties of theoretical models, such that the concept of General Equilibrium actually becomes useful for analyzing real economies and real problems”.

And for Bergman et al, “CGE model is an appropriate substitute for an analytical general equilibrium model whenever the size and the complexity, in terms of the number of households and the production sectors, make such a model mathematically intractable. It’s useful whenever the magnitude, and thus not only the sign, of the impact of changes in exogenous conditions on key economic variables are to be estimated. It also may be useful simply because it can help the analyst to identify general equilibrium effects of changes in exogenous conditions that were not obvious”.

These models present the following advantages: they easily adapt to the treatment of problems of various forms; based on rigorous data, they impose a theoretical coherence, as well as an explicit presentation of the hypotheses of most models makers. They also permit to take into account, the links between different sectors of an economy.

However, it appears important to note on the other hand in terms of limits observed in literature that, they are quite complex models that for example do not accept data showing any signs of incoherence.

The contributions of the authors at the origin of this type of particular modelling that constitute CGE models verity without any ambiguity, these definitions proposed above, which stress very much the interest, the role and the quality of CGE models. It appears therefore appropriate to present them. **The three CGE models founders work**

**Johansen and the MSG model**

Norwegian economist, Johansen presents in 1960 a model (MSG) which would be globally perceived as the first CGE model. The author was very much interested by the construction of a model capable of approximating or reflecting reality, focusing principally on long term structural changes on the key variables of the economy (accumulation of capital) and economic growth. He conceives it originally as a tool for forecast and for the evaluation of a long term economic policy.

Using Walrasian’s theory of general equilibrium as support, Johansen’s model identifies itself by the fact that it postulates certain ‘ad hoc’ hypotheses: on one hand, concerning the rate of remuneration of salaries and the returns rate of capital, though these factors are entirely mobile amongst sectors, their remuneration rate at equilibrium in each
sector are different. On the other hand, persistent differences between sectors equally concern the composition of labour force, monopolistic degree of products, working conditions. Given these particular conditions, a model entirely based on the theory of general equilibrium was not appropriate.

This model fast became, in Norway, a key instrument for forecast and planning, and then was enlarged in all sorts of horizons. Some modifications brought to the base structure, such as a considerable treatment, more advanced of substitution factor as well as the demand for energy have permitted to obtain a more recent version, ‘MSG-EE’, specially designed for the analysis of those questions relative to the utilisation of energy and environmental solution. The ORANI model, CGE model elaborated for the examination of pre-mentioned questions on the occasion of the Australian economy, equally takes Johansen’s model as reference. This MSG model has equally had a signification influence on the elaboration of CGE models in developing countries.

Scarf’s algorithm approach

Scarf’s contribution which constitutes in a calculating approach of Walras’ general equilibrium is another starting point for the development of applied modelling ‘CGE’. With the help of Scarf’s approach, Shoven and Whalley conceived a computer science procedure for the determination of a general equilibrium with taxes.

Scarf’s approach then being an integral part of Harberger’s first works, constituted the frame of a great inspiration opening up on a series of researches concerning the analysis of taxes and questions on commercial policies in the context of Walrasian model of general equilibrium, and that of Hecksher-Ohlin.

We equally find in writings, other contributions that follow the same methodology, but focus instead on question of international trade, and of resource allocation in a small open economy.

Contrary to the MSG model, most works that was left in the tradition of the algorithmic approach of Scard-Shoven-Whalley tended more to uniqueness with theory; they firmly fixed on the Walrasian theory of general equilibrium, interested particularly in the efficiency and distributive effects of various majors of economic policies.

Jorgenson: Econometric modelling of general equilibrium

Econometric modelling in the framework of general equilibrium has known a development thanks to several contributions from Jorgenson, his works constituted of the elaboration of CGE models characterised on one hand by the use of econometric techniques, in particular recourse to these methods for the estimation of parameters used, and on the other hand, by their anchorage to the neoclassic theory. In their work concerning the American economy, Hazilla and Koop remain in that tradition of recourse to econometrics initiated by Jorgenson.

This approach – based on the usage of econometrics – distinguishes itself from the usual approach borrowed by the other CGE models, in which parameters of supply and demand functions are estimated by another technique: Data calibration.

Jorgenson devoting his work to the study of the American economy; dynamics models that he makes have as objective, evaluate the effects on welfare and growth, of various policies based on taxation, to simulate energy policies in the USA, in the 1970’s, following the CGE econometric model for the analysis of energy policies particularly, in the field of environmental economics, studies dynamic effects of environmental policies.

A Classification of categories of applied models

Following the first applied models, numerous models based on algorithms have been developed; relying on real data of one or more economies, CGE models are more and more used – specially with the development
of computer sciences – in different fields of economics for the analysis and simulation of several policies (reform analysis on the fiscal plan, economic integration, agricultural policies, energy policies).

According to their spatial application (regional, national, global models), of choices of the variables intervening in the model, or temporal criteria (static or dynamics models), we can distinguish several types of CGE applied models.

**Classification following a special approach**

We can distinguish in this section models applied to a country on one hand (single-country model); they generally present that characteristic of being very detail in terms of the number of sectors and households, and are generally used for the analysis of specifies policies within a given country. The models of Jorgenson and Wilcoxen, Gonzalez and Dellink that study the impact of climatic policies on the economies of a country constitute some examples.

On the other hand, literature got enriched of models applied to a group of countries (multi country model) following the GEM-E3 applied to countries of the European Union. Beyond, there exist global types of models (global country model) such as OECD’s GEEN, MERGE, DICE, Whalley and Wiggle model, applied to a group of regions of the entire planet. These models are conceived for the analysis of transboundary pollutions.

**Bottom-up and Top-Down models**

Models said to be bottom-up are those that present an advanced disintegration of energy sector and, consider specific energy technologies with specific technical parameters; they however are defect in that they neglect feedback effects in the economy, as well as the effects on energy markets.

On the opposite, top-down models according to Peterson, are very macroeconomic models. As such, are included in this category, input/output models, macro econometrics models, and CGE models proper.

**Classification according to a temporal criterion: Static and dynamics models**

Concerning the temporal criterion, applied models can indeed be distinguished by their static or dynamic structure (intertemporal). As modelling aspect is concern, what differentiates them particularly, is the absence or not accumulation of capital. Dellink underlines that most works, Bergman, Conrad and Schroder, Dellink and Jansen, Naqvi, Parry and Williams that highlight some applied models in general equilibrium and treat environmental questions, use models with static structures.

Devaragian and Go supports that dynamics models are very much developed in economic literature in general, and those who integrate environmental questions are rather few. However, as could (be) confirming by the observation of synthesis of applied models below (cf. 5.1), dynamic CGE models in environmental economics have known since then, a rapid evolution. The works of Jorgenson and Wilcoxen, based on long term data of the American economy, as well those of Böhringer, Böhringer and al., constitute references.

Dellink realises a supplementary type of applied models, purely dynamic. As such, he opts for an approach that distinguish three types of models, namely, steady-state models, recursive dynamics like DART, EPPA, GREEN, and forward-looking models following the example of WIAGEM, GTEM.

It is in this category of models (forward-looking) that we find models with overlapping generations in which agents have a finite live horizon (different from that of the model’s horizon) and dynastic models in which agents in finite number have a rather infinite horizon of life.

On the technical plan of the construction of models, the transition from a static to a dynamic structure is done by means of integration of recursively mechanisms, in the model initially considered as static.

Beyond, once this distinction carried out, models taken individually in each category
can be distinguishable by other criteria. Even though belonging to the same universe on the method path, they generally present in their specified category, significant differences such as the number of sectors of production, the number of primary factors.

**Synthesis of the type and structure of models applied to the environment**

Models below are generally based on the Kyoto Protocol, and present a reduction scenario of GES by tax policies or tradable emission permits, try to evaluate in function of their various hypothesis (used energy, nature of GES emissions), economic impacts of climate changes, the consequences of these changes on wellbeing.

1. ‘The use of single-generation models obscures the relationship between allocative efficiency and intergenerational equity in competitive intertemporal economies


3. Quantifying the impact of specific policies on the equilibrium allocation of resources and relative prices of goods and factors.


5. See Shoven and Whalley, [1992], Shoven and Whalley, [1984].

6. See Manne & Richels, (1999), or for many details, on this models, see Weyant (1999).

**Some applied models in the light of literature**

<table>
<thead>
<tr>
<th>Models</th>
<th>References</th>
<th>Region</th>
<th>Number of sectors</th>
<th>Structure</th>
<th>Top-down/Bottom-up</th>
</tr>
</thead>
<tbody>
<tr>
<td>GEM-E3</td>
<td>Capros &amp; al.[1997]</td>
<td>EU + ROW</td>
<td>18</td>
<td>Dynamic</td>
<td>Top-down</td>
</tr>
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<td></td>
<td><a href="http://gem-e3.zew.de/">http://gem-e3.zew.de/</a></td>
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<tr>
<td>BFR</td>
<td>Böhringer &amp; al. [1998]</td>
<td>German, France, UK, Italy, Spain, and ROW</td>
<td>23</td>
<td>Static</td>
<td>Top-down</td>
</tr>
<tr>
<td>HRW</td>
<td>Harrison &amp; al. [1989]</td>
<td>France, USA, Japan, UK, Ireland, German, Holland, Belgium, Danemark, and ROW</td>
<td>6</td>
<td>Static</td>
<td>Top-down</td>
</tr>
<tr>
<td><strong>Multi Countries Models</strong></td>
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<tr>
<td><strong>Global’ Models</strong></td>
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<tr>
<td>EPPA</td>
<td>Yang &amp; al. [1998]</td>
<td>12</td>
<td>Recursive dynamic</td>
<td>Top-down</td>
<td></td>
</tr>
<tr>
<td>DART</td>
<td>Klepper &amp; al. [2003]</td>
<td>11</td>
<td>Recursive dynamic</td>
<td>Dynamic</td>
<td></td>
</tr>
<tr>
<td>EDGE</td>
<td>Jensen &amp; Thelle [2001]</td>
<td>8</td>
<td>Dynamic</td>
<td>Top-down</td>
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<tr>
<td>G-Cubed</td>
<td>McKibbin &amp; al. [1999]</td>
<td>8</td>
<td>Dynamic</td>
<td>Top-down</td>
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<tr>
<td>GTEM</td>
<td>Tuluple &amp; al. [1999]</td>
<td>18</td>
<td>Dynamic</td>
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**Journal of Environmental Research And Development**

Vol. 2 No. 1, July-September 2007

<table>
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<tr>
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<th>Year</th>
<th>Structure</th>
<th>Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>MERGE</td>
<td>Manne &amp; Richels</td>
<td>1999</td>
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<tr>
<td>MS-MRT</td>
<td>Bernstein &amp; al.</td>
<td>1999</td>
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<tr>
<td>PACE</td>
<td>Böhringer</td>
<td>2002</td>
<td>Dynamic</td>
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<tr>
<td>WIAGEM</td>
<td>Kemfert</td>
<td>2001</td>
<td>Dynamic</td>
<td></td>
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<tr>
<td>RICE</td>
<td></td>
<td></td>
<td>Dynamic</td>
<td>Top-down</td>
</tr>
<tr>
<td>WorldScan</td>
<td>Bollen &amp; al.</td>
<td>1999</td>
<td>Dynamic</td>
<td>Top-down</td>
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<tr>
<td>AIM</td>
<td>Kainuma &amp; al.</td>
<td>1999</td>
<td>Dynamic</td>
<td>Top-down</td>
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<tr>
<td>CRTM</td>
<td>Rutherford</td>
<td>1992</td>
<td>Dynamic</td>
<td>Bottom-up</td>
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<tr>
<td>WW</td>
<td>Whalley &amp; Wigle</td>
<td>1991</td>
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<td>Global2100</td>
<td>Manne &amp; Richels</td>
<td>1992</td>
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<td>IIAM</td>
<td>Harrison &amp; Rutherford [1997]</td>
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</table>

**‘Single Country’ Models**

<table>
<thead>
<tr>
<th>References</th>
<th>Country</th>
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<th>Structure</th>
<th>Characteristics</th>
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<tr>
<td>Hazilla &amp; Kopp [1990]</td>
<td>USA</td>
<td>36</td>
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<td>Econometric estimation of parameters</td>
</tr>
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<td>Bergman [1990]</td>
<td>Sweden</td>
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<td>Static</td>
<td>Tradable emission quotas</td>
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<td>Parry &amp; al. [1998]</td>
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<td>6</td>
<td>Dynamic</td>
<td>Quotas of CO2 and taxes</td>
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<tr>
<td>Jorgenson &amp; Wilcoxen [1993]</td>
<td>USA</td>
<td>35</td>
<td>Static</td>
<td>Econometric estimation of parameters</td>
</tr>
<tr>
<td>Alfsen &amp; al. [1996]</td>
<td>Norway</td>
<td>33</td>
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<td>Vennemo [1995]</td>
<td>Norway</td>
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<tr>
<td>Farmer &amp; Steininger [1999]</td>
<td>Austria</td>
<td>8</td>
<td>OLG model</td>
<td>Various generations</td>
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<td>Hill [2001]</td>
<td>Sweden</td>
<td>17</td>
<td>Dynamic</td>
<td></td>
</tr>
<tr>
<td>Xie &amp; Saltzman [2000]</td>
<td>China</td>
<td>7</td>
<td>Static</td>
<td>Specific sector of reduction of the emissions</td>
</tr>
</tbody>
</table>

**Steps adopted by Applied models of general equilibrium**

The following diagram inspired by Shoven and Whalley, indicates the various steps of elaboration of applied model for general equilibrium. Some segments of this diagram present particular characteristics that it should be underlined with respect to their importance: it is about the construction of social accounting matrix, calibrating and the specification of exogenous/endogenous variables.

**Social accounting matrix (SAM)**

It can be defined as being generalisation of the economic exchange table (EET) of the national accountancy. The construction of such a matrix is essential for calibration that follows. Data from SAM have to respect certain basic conditions – reason for which adjustments are usually essential before calibrating, for instance:

- Supply maintains equilibrium with demand for each good and each factor of production (commodity balance);
For every institution, total revenue corresponds to total expenditure (flow of funds balance);

- Macroeconomic equilibrium, that is to say equality between savings and investment.

Parameter calibration

Variables of a model, whatever they are, are of two types: exogenous variables, that are determined out of the model, and endogenous variables, determined inside the model (by exogenous variable). The model thus applies a link of cause-effect between the variables, which are précised by the modeller during its construction.

As essential characteristic of the approach by general equilibrium is that all price and quantity variables are endogenous; these determined simultaneously at the equilibrium. Consequently, only those parameters that characterise agents such as utility functions, production functions, initial endowments and eventually instruments of economic policy can be considered as exogenous.

Calibration can be assimilated to a ‘determinative approach’ that will consist in choosing the parameters of the model (initial endowment, utility and production functions) in such a way that the values of endogenous variables of general equilibrium, calculated by the model may be as close as possible to the values observed in the economy, at a given date, chosen as reference. In the other words, this operation consists in ‘blocking’ the model disposable data. With such calibrated values, we obtain a specification of the reduced scale model of the economy, specification from which simulations of economic policies are affected.

Particular case of models with Overlapping generations (OLG)

General considerations

Proposed by Allais, Samuelson and Diamond, models with overlapping generations, more and more used in economic literature, have become a reference tool besides neoclassical economists as from the 1970’s, with the same status as models with...
representative agents having infinite life span following Ramsey$^{34}$. If they are called thus, it is because they consider successive generations of agents who live during several periods (at least two). Contrary to the traditional theory, these models consider sequences of generations with infinite life duration; in other words, generations of individuals, behaving according to the theory of life cycle, and the primary version, devoid altruism$^{35}$. Each generation trying to work out a way of exchanging with predecessor and that which comes after it. The goal of these exchanges is the search for intertemporal allocation of efficient and respectful resources of futures generations.

At every time $t$, coexists, during at least one period in the economy, agents of different ages, at a different stage of their life cycle. This hypothesis is as much sufficient for the study of all economic problems consisting of transfer appears evidently in environmental problems.

In environmental economics, the usage of OLG models as frame of analyses remains recent enough; this methodology constitutes an appropriate framework for the analysis of correlations between environmental quality and revenue, when agents with short life spans are those who take decisions concerning the accumulation of capital and the quality of the environment. This approach helps find solutions to the following question: How do we reconcile the temporal horizon of the environment which is without any doubt the long term, having as short term public productive – consumptive – decisive agent?

From a methodological point of view, as taken down by Fodha$^{36}$, articles using OLG models for treatment of environmental problems always follow the same approach: we start by determining the competitive equilibrium, then show its efficiency by comparing it to the optimum. The control of environmental externalities as a whole is only permitted by the presence of a social planer; then we try to decentralise this optimum by the means of different vectors$^{37}$.

**OLG models and environmental problems**

OLG models connection to environmental problems can differ according to a good number of criteria in function: of the origin of the population (depending on if it is linked to an input, output or to consumption), of the impact of the pollution (depending on if it is situated at the level of production or the utility of agents), of preferences of agents (be they selfish or altruistic), of the presence or not of a technology of cleaning up, of the instrument of environmental policy used, in this case tradable emission permits, taxation for example.

In this last case listed above, most contributions with OLG models use taxation as an implementation instrument.

Amongst exceptional works that use tradable emission permits, our attention will be pulled to those that treat problems of pollution and/or global warming.

A sum up of different OLG models in function of environmental policy instruments used (taxes, tradable emission permits, transfers) treating environmental problems is presented as follow$^{38}$. Once this synthetic presentation effected, we will turn ourselves on the case OLG models that use tradable emission permits and that treat about problems of air pollution and/or global warming.

** Tradable emission permits as an instrument of environmental policy in the light of OLG models**

In general, studied works rely on the methodological structure of OLG models specified in the sub-section 6.1. It’s also the case of models quoted below. Generally, these models start from the idea that the accumulation of GHG resulting from economic activity is probably the resultant of abusive and uncontrolled use of absorption capacities of the
atmosphere. Indeed, the greatest part of these emissions comes from the production activity of industrial firms, which maximize their profit in a perfectly competitive framework.

Summary table of OLG models and environmental policies

<table>
<thead>
<tr>
<th>Models</th>
<th>Instrument of policy used</th>
<th>Origin of pollution impact</th>
<th>Clean up materials</th>
<th>Agents’ Preferences</th>
</tr>
</thead>
<tbody>
<tr>
<td>Howarth &amp; Norgaard [1992]</td>
<td>Taxation</td>
<td>Consumption of energy by firms (Input) consumption</td>
<td>No</td>
<td>Egoists</td>
</tr>
<tr>
<td>John &amp; Pecchenino [1994]</td>
<td>Intirely Internalisation of externality trough intergenerational transfers</td>
<td>Affect the production negatively</td>
<td>Yes</td>
<td>Egoists</td>
</tr>
<tr>
<td>John &amp; al. [1995] Egoists</td>
<td>Transfers conditioned by the sub/over accumulation of capital and lower or upper quality of the environment</td>
<td>Consumption</td>
<td>Agents’ utility</td>
<td>Yes</td>
</tr>
<tr>
<td>Lambrecht [2005b]</td>
<td>Tradable permits</td>
<td>Production</td>
<td>Utility</td>
<td>Yes</td>
</tr>
<tr>
<td>Jouvet &amp; al. [2004]</td>
<td>Tradable permits</td>
<td>Production</td>
<td>Utility</td>
<td>No</td>
</tr>
<tr>
<td>Ono [2002]</td>
<td>Tradable permits</td>
<td>Production</td>
<td>Utilité</td>
<td>Yes</td>
</tr>
<tr>
<td>Gerlagh &amp; Van der Zwaan [2001]</td>
<td>Tradable permits</td>
<td>Input</td>
<td>Utilité</td>
<td>No</td>
</tr>
<tr>
<td>Stephan &amp; al. [1998]</td>
<td>Tradable permits</td>
<td>Input</td>
<td>Production</td>
<td>No</td>
</tr>
<tr>
<td>Stephan &amp; Müller-Fürstenberg [1998]</td>
<td>Tradable permits</td>
<td>Input</td>
<td>Production</td>
<td>No</td>
</tr>
<tr>
<td>Howarth [1998]</td>
<td>Taxation + Intergenarional Transfers</td>
<td>Production</td>
<td>Production</td>
<td>No</td>
</tr>
</tbody>
</table>

In this paper, we deal only with those models in which tradable emission permits are used as an environmental policy instrument. As recall, they make assumptions of agents living several periods; these agents work when they are young, and consume when they are old.

As in Lambrecht, agents’ revenue is affected to savings and to the maintenance of environment. Thus, their utility depends on consumption and the quality of environment; consumption being an inverse function of the quality of the environment left to future generations. In this model, it is theoretically shown that since the introduction of a tradable emission permits system in the economy can stimulate the accumulation of capital in reference to the “laissez-faire” equilibrium, thus, it is not neutral on the initial price equilibrium system. Furthermore, introduction of an environmental maintenance system which is a form of investment, financed by a tax system striking young households, can generate a negative substitution effect, and also and income effect rather positive to the accumulation of capital; when the income effect compensates the substitution effect, loosening of constraints on emission can simultaneously increase capital and the quality of environment.

Ono using tradable quotas allocate to control the pollution in a similar theoretical framework to the precedent, point out existence of an ambivalent cumulative revenue effect (positive and negative). So according to his results, the author recommends a particular
attention on consequences at the long run of environmental policies based on the emission permit system.

However, in Jouvet et al.\textsuperscript{41}, agents’ utility depends on consumption when they are young, on time devoted to work (which is opposite of leisure) and the quality of environment; then in the second period of life cycle, simultaneously on consumption and quality of environment, elder do not work. In an optimal growth model involving the pollution phenomenon, Jouvet et al.\textsuperscript{42} show that efficiency necessitates that tradable emission permits should not be allocated to firms following the modality of ‘grandfathering’, in opposition to habitual visions and practices.\textsuperscript{43-49}

**CONCLUSION**

Problems posed by environmental pollutions and their direct harmful consequences with an intergenerational dimension such as climate change, require without any doubt, among the solutions the taking into account of intergenerational equity criterion. These considerations – of equity – appeared in the theory of optimal growth as from the foundation of Ramsey article’.\textsuperscript{1}

Actions that have an impact on the environment as well as environmental decisions have implications on the economic growth and the accumulation of capital; they affect macroeconomic variables as a whole, and because of this, probably modify the economic equilibrium. Decisions generally taken on a short temporal dimension by deciders referred to as ‘short-sighted’ as concerns the quality of the environment, present limits in the ‘internalisation’ of long term external effects.

The aim of this work was on one hand; to situate applied modelling on general equilibrium in literature; on other hand, we were interested in the case overlapping generation models; with a particular attention on those which concerned with environmental problems and tradable emission permits.

The principal limit which can be underline is that these models presented above remain theoretical. These questions of long term effects of externalities are favourable to applied modelling. So, starting from a data base, we prospect to build a more realistic applied OLG model, according to Rasmussen and Rutherford works on applied OLG models with GAMS. The aim will be to study effect of GHG abatements on French economy (with environmental policy through tradable emission permits) in an OLG approach.

**REFERENCES**


