Università degli Studi di Padova
Dipartimento di Ing. Civile, Edile e Ambientale

Corso di Laurea in Mathematical Engineering

Project in Dynamical Systems

Economic growth and Environmental pollution

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1 Introduction

Understanding the causes behind the huge differences in standards of living across countries has been a central issue in economics since the time of classical economists. Economic growth is an issue that, as Robert Lucas (1988, p. 5, cited in [?]) points out: "Once one starts to think about [economic growth], it is hard to think about anything else." Traditionally economists were concentrated in the growth theory and regularization in the growth process, and not much attention has been given to the relationship between economic growth and the environment until recent decades. To quote a statement from [?], "Received growth theory is biased. It neglects to take into account the pollution costs of economic growth." Therefore, in the last decades, several research has been undertaken which tries to explore the links between economic growth and the environment, especially regarding issues associated with the impact of natural resources on growth processes and sustainability. Consequently, in the last years, growth theory has taken into account also the interrelationships between environment pollution, capital accumulations and the growth of variables which are of central importance in that theory. There are some evidence about growth that economists have long taken for granted, and they are based of five basic facts (see Paul Romer 1994, p. 12, [5]):

1. There are many firms in a market economy.
2. Discoveries differ from inputs in the sense that many people can use them at the same time.
3. It is possible to replicate physical activities.
4. Technological advance comes from things that people do.
5. Many individuals and firms have market power and earn monopoly rents from discoveries.

If the environmental dimension is to be incorporated into the main body of growth theory, then a sixth fact should be added:

6. There is joint production of a flow of waste material that degrades the environment, and environmental quality is positively valued by individuals.

The purpose is therefore to explore how fact six is incorporated into modern growth theory, and it concentrates on the relationship between economic growth and environmental pollution.

The evolution of growth theory since the 1950s has passed through two main stages. The basic feature of the first stage, which originated with the Solow model (see [6, Solow], [7, Swan]), is that technical change is exogenous. This means that growth rates cannot be affected by the government policy. In this stage, growth is analyzed either in terms of models with exogenous saving rates (the Solow–Swan model), or models where consumption and hence savings are determined by optimizing individuals. These are the so-called optimal growth or **Ramsey models** ([4, Ramsey], [2, Cass], [3, Koopmans]). The main feature of the second stage that emerged in the 1980s is that technical change is endogenized in such a way that economic growth is associated with an endogenous outcome of the economic system rather than with exogenous forces. In the context of endogenous growth models, growth rates can be affected by government policies. The purpose with this work is to explore vital questions such as:

- is environmental protection compatible with economic growth;
- is it possible to have sustained growth in the long run without accumulation of pollution;
- what is the impact of environmental concerns on growth, and in particular, how are the levels, the paths or the growth rates of crucial variables such as capital, income, consumption or environmental pollution affected if we take into account the environment;

» TODO... Must add the structure of the article here...

Nonetheless, this work is based also on the paper [1] with focus on the model 2.2 [The Ramsey-Cass-Koopmans Model With Environmental Pollution].

2 The environmental pollution model

The model will unify the process of economic growth with the environment, an economic model describing technology and preferences which characterize the economic problem should be linked to the environmental module which describes the natural process characterizing pollution accumulation. Relation between economic and environmental module is motivated by the following facts:

- Environmental pollution is a by-product of production or consumption processes taking place in the economic module.
- Emissions generated in the economic module affect the flow or the accumulation of pollutants in the ambient environment (e.g., emissions of sulphur oxides, noise, carbon dioxide accumulation in the atmosphere, or phosphorus accumulation in water bodies).
- Environmental pollution has detrimental effects on the utility of individuals.
- Environmental pollution could have detrimental productivity effects, while improvements in environmental quality might have productivity enhancing effects.

Consequently, given a neoclassical aggregate production function for the economy,

$$Y = F(K, AL), \tag{1}$$

where K is the capital stock and AL is the effective labour[1], to allow for labour augmenting technical change, the flow of emissions at time t can be written as

$$Z(t) = v(Y(t)). \tag{2}$$

[1]In the context of a Solow model, if labour time is denoted by L and labour's effectiveness, or knowledge, is A, then by effective labor one means AL. In general means 'efficiency units' of labour or 'productive effort' as opposed to time spent.

One can also specify (2) as $Z = \phi Y$, where ϕ is the unit emission coefficient, that is, emissions per unit of output. Emissions reducing technologies can be incorporated by further specifying the unit emission coefficient as $\phi(K)$, with $\phi'(K) < 0$ for $K \in \mathcal{K} \subset \mathcal{R}_+$. From this assumption it is clear that if the capital stock accumulates, new "cleaner" techniques are used.

Esempio di equazione. Ok, quindi avete visto come si fa per generare una tabella o inserire una figura. E per quanto riguarda le Equazioni?
Semplice, nel modo seguente

$$R_{\mu\nu} - \frac{1}{2} R g_{\mu\nu} + \Lambda g_{\mu\mu} = \frac{8\pi G}{c^4} T_{\mu\nu} \tag{3}$$

E la si richiama nel testo con il solito comando *ref*, quindi l'Equazione di Campo di cui sopra è l'Eq. 3.
Se ho necessità di scrivere più formule consecutivamente, si usa eqnarray:

$$\frac{\partial \mathcal{D}}{\partial t} = \nabla \times \mathcal{H} \tag{4}$$

$$\frac{\partial \mathcal{B}}{\partial t} = -\nabla \times \mathcal{E} \tag{5}$$

$$\nabla \cdot \mathcal{B} = 0 \tag{6}$$

$$\nabla \cdot \mathcal{D} = 0 \tag{7}$$

E se invece di quattro le voglio considerare come fosse una sola:

$$\begin{aligned} \frac{\partial \mathcal{D}}{\partial t} &= \nabla \times \mathcal{H} \\ \frac{\partial \mathcal{B}}{\partial t} &= -\nabla \times \mathcal{E} \\ \nabla \cdot \mathcal{B} &= 0 \\ \nabla \cdot \mathcal{D} &= 0 \end{aligned} \tag{8}$$

3 Growth and Environmental pollution in the Solow model

Write down here the text

4 Optimal growth and Environmental pollution

Write down here the text

4.1 The Ramsey–Cass–Koopmans model with environmental pollution

Write down here the text

5 Conclusion

Write down the conclusions here!!!

References

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[6] Robert M. Solow. A Contribution to the Theory of Economic Growth. *The Quarterly Journal of Economics*, 70(1):65–94, 1956.

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