Nonlinear dynamics and global indeterminacy in an overlapping generations model with environmental resources

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ABSTRACT

We analyse the dynamics of an economy formed of overlapping generations of individuals whose well-being depends on leisure, consumption of a private good and a free access environmental resource. The production activity of the private good deteriorates the environmental resource. Individuals may defend themselves from environmental degradation by increasing consumption of the private good, which may be perceived as a "substitute" for services provided by the environmental resource. However, the resulting increase in production and consumption of the private good generates a further increase in environmental deterioration leading economic agents to increase production and consumption of the private good itself. This substitution mechanism is clearly self-reinforcing and may fuel an undesirable economic growth process according to which an increase in consumption of the private good – and the resulting increase in Gross Domestic Product – is associated with a reduction in individuals' well-being. The article shows the emergence of several global phenomena, and individuals' expectations about the future evolution of the environmental quality can give rise to (local and global) indeterminacy about the growth path the economy will follow starting from a given initial position.

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1. Introduction

In this article, we analyse the dynamics of an economy composed of a continuum of identical individuals whose well-being depends on leisure, consumption of a private good and a free access environmental resource. The production activity of the private good deteriorates the environmental resource. Individuals may defend themselves from environmental degradation by increasing the consumption of the private good, which may be perceived as a "substitute" for the environmental resource. However, the resulting increase in consumption and production of the private good generates a further increase in environmental deterioration leading agents to a further increase in production and consumption of the private good itself. This substitution mechanism is clearly self-reinforcing and may fuel an undesirable economic growth process according to which an increase in production and consumption of the private good – and the resulting increase in Gross Domestic Product (GDP) – is associated with a reduction in individuals' well-being.

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In the model, individuals are assumed to have perfect foresight, i.e. they perfectly foresee the time evolution of economic variables. The state of the economy is characterised by a state variable K_t – that represents the stock of productive capital of the representative firm at time t – and by a choice variable ℓ_t – that represents the labour supplied by the representative individual in the production process of the consumption good at time t. The stock of capital K_t is considered as a pre-determined variable as its initial value K_0 is determined by "history" (see the seminal article of [27]), and therefore it is considered as a given. In contrast, the initial value of the labour supply ℓ_0 is chosen by the representative individual in order to maximise his lifetime utility. Therefore, ℓ_t is a jumping variable and its initial value is determined by taking into account the individual expectation about the future evolution of environmental quality, which is negatively affected by the average production of the consumption good.

As the economy is comprised of a continuum of identical agents, the impact of each single individual's choice on environmental quality is negligible. Therefore, the representative individual takes environmental quality as exogenously given. In this context, individuals may not be able to coordinate their choices and coordination failures may arise. More specifically, given the initial value K_0 of the pre-determined variable K_t, the initial value ℓ_0 of the choice variable ℓ_t may not be uniquely determined and phenomena of local and global indeterminacy may occur. The local indeterminacy phenomenon is observed when the dynamic system describing the evolution of capital and labour admits a locally attracting fixed point (K^*, ℓ^*). In such a case, if the (pre-determined) initial value K_0 is close enough to K^*, then there exists a continuum of initial values ℓ_0 such that the trajectory starting from (K_0, ℓ_0) approaches (K^*, ℓ^*). In this case, we have indeterminacy as there does not exist a unique choice of ℓ_0 that leads the economy to approach (K^*, ℓ^*). The choice of ℓ_0 by each individual depends on his expectation about the other individuals' choices of ℓ_0.[3] In contrast, global indeterminacy occurs when, by starting from a given initial value K_0, the economy may converge to different fixed points (or, more in general, different invariant sets such as cycles, closed invariant curves or chaotic sets) according to the choice of the initial value ℓ_0. In case of global indeterminacy, different initial choices of the non-predetermined variable ℓ_t may imply different long-term behaviours and the initial value of the state variable does not necessarily determine the set to which the economy will eventually converge.

The analysis of the linearisation of a dynamic system around a fixed point gives all information required to detect local indeterminacy. The relative simplicity of the local analysis explains the reasons why a large amount of works in the literature focuses only on local indeterminacy issues (see [9]). However, a fast growing number of contributions deal with dynamic systems exhibiting global indeterminacy (see, amongst others, [4,5,10–14,18,21,22,30–32]). Global indeterminacy is usually observed in highly nonlinear systems and is detected by global analysis techniques. The contribution of the present work to the literature on indeterminacy is the analysis of the role played by the interaction between environmental degradation and individuals' consumption/investment choices in generating nonlinearities and very complex scenarios of global dynamics. Different from the main body of the literature on global indeterminacy, where indeterminacy is generated by market imperfections in the production sector, the focus of this work is on the demand side of the economy. In particular, in the model indeterminacy is produced by choices of individuals who defend themselves against environmental degradation by consuming higher quantities of private consumption goods. The present article extends the analysis of Antoci and Sodini [3] and Antoci et al. [6], where the negative relationship between environmental quality and aggregate production of the private good is linear. Specifically, we consider a nonlinear dependence between these variables and obtain more complex dynamic scenarios. This article is also related to the literature on environmental defensive expenditures. In the model, the more interesting dynamic scenarios take place under the assumption of substitutability between the private consumption good and environmental quality. Economic growth in industrialised countries is often associated with a substitution process according to which the services provided by free access environmental resources are substituted by the consumption of (costly) private goods (see, amongst others, [8,25,28,29]). The degradation of coastal areas next to urban centres can motivate costly trips to less contaminated areas by car, boat or airplane. Individuals buy mineral water when tub water is non-drinkable, double windows and medicines to protect themselves against, respectively, traffic noise and pollution-related diseases. Air conditioners provide a paradigmatic example of the self-enforcing process analysed in the article [2]. These devices cool the interior of homes and offices and then protect individuals against global warming. However, they produce an increase in the external temperature that tends to encourage their use even further.

According to the literature on environmental defensive expenditures, the GDP level of an economy is not a good proxy of individuals' well-being. This because the methodology used to measure GDP accounts for defensive expenditures but does not evaluate environmental degradation. Consequently, the positive effect due to an increase in GDP may be more than compensated by the deterioration of natural resources (see [17]). We show that growth orbits along which the increase in production/consumption of the consumption good (i.e., the increase in GDP) generates a reduction in individuals' well-being may exist even if individuals are rational. The process of well-being reducing economic growth is observed if coordination failure occurs: given the initial value K_0 of the capital stock, individual well-being would be higher by choosing a lower initial value ℓ_0. However, no individual has an incentive to modify his choice of ℓ_0 if the other individuals do not do the same.

The rest of the article is organised as follows. Section 2 describes the model. Section 3 illustrates some basic properties of dynamics. Section 4 highlights some global dynamics properties through numerical simulations. Section 5 concludes.

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[3] In this kind of models, it is usually assumed that all individuals make the same initial choice of ℓ_0.