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Economic growth and polluting resources: Market equilibrium and optimal policies

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ABSTRACT

This paper develops an endogenous growth model to study the decentralized equilibrium and the optimum conditions in an economy which uses polluting resources. The model includes two policy instruments, a subsidy to final consumption and an emissions tax. It also considers two forms of endogenous technical change, pollution-reducing knowledge and horizontal innovation. We show that, if the efficiency of knowledge to reduce emissions is sufficiently high, a higher output is compatible with lower emissions in both levels and growth rates. Additionally, if the two instruments are used together the economy may achieve a higher output and lower emissions since the subsidy may offset, at least partially, the negative tax effects.

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1. Introduction

In this article we aim to analyze the compatibility between economic growth and a cleaner environment in a framework where production requires polluting resources and there is environmental policy. Our endogenous growth model assumes two forms of technical change: horizontal innovation in the natural resource sector and pollution-reducing knowledge accumulation in the final-goods sector. We start by analyzing the decentralized steady-state equilibrium. Then, we explore the policy implications when the government uses two policy tools, a tax on emissions and a subsidy to final consumption. After that, we derive the policy conditions under which the decentralized equilibrium is optimal. Finally, we perform a simple numerical exercise.

The set-up of our model follows Grimaud and Tournemaine (2007) (hereafter GT), but we depart from their model in several aspects, including our main focus. Firstly, in GT, growth is sustained by human capital accumulation and no natural resources are considered. The authors found that a tighter environmental policy promotes growth since it enhances the willingness of individuals to acquire education. We analyze an alternative path to harmonize the economy and the environment and, for that, we adapt the final-goods production function to use only natural resources which generate emissions.[1] Secondly, we assume horizontal innovation in the natural resources sector in an attempt to include something new in the literature. Throughout time scientists have found ways to use resources that were not usable before. For instance, uranium was not particularly useful before the development of the nuclear fission technology. These innovations increase the variety of usable natural resources. This type of differentiation, in line with Barro and Sala-i-Martin (2004, Ch. 6), among other, implies that when new resource varieties are discovered or made usable old ones do not become obsolete. Finally, we depart from GT by assuming that final-goods producers invest a given amount of their own product (instead of human capital) to generate knowledge, i.e., our model is lab-equipment and not knowledge driven (e.g., Rivera-Batiz and Romer, 1991).

Our model shows that, in the decentralized equilibrium, if the efficiency of knowledge to reduce emissions is sufficiently high, higher output is compatible with lower emissions both in their steady-state

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[1] Apart from the endogenous growth debate on the consideration of human capital accumulation and physical capital, we do not consider these production factors as mainly instrumental for the isolation of the effects of natural resources on economic growth and environment. For the same reason, we also abstract from the labor market (as, e.g., Grimaud and Tournemaine, 2007; Schou, 2002).There is no doubt that considering additional production factors would increase realism in our model, notwithstanding, the analysis would be more complicated at the risk of losing our main focus: the role of natural resources.

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levels and their growth rates. Additionally, if the government uses the two instruments together it may achieve a higher output and lower emissions since the subsidy may offset, at least partially, the negative output effects of the tax. The derivation of the economic optimum gives the conditions to impose on public policies in order to achieve an optimal equilibrium. Our empirical application shows that the catching-up process between a developed and a developing country is faster in the central planner (optimum) situation than in the decentralized equilibrium.

The economic growth literature dealing with natural resources has often focused on the conditions of growth under scarcity, but has at times ignored a key aspect: resource use generates pollution (e.g., Barbier, 1999; Garg and Sweeney, 1978; Grimaud and Rougé, 2003; Scholz and Ziemes, 1999). Fossil fuels combustion and mineral resources are, in fact, responsible for a large share of anthropogenic pollution, and policies have been conducted worldwide in an attempt to reduce environmental problems (e.g., Halicioglu, 2009; Sadorsky, 2009; Soytas and Sari, 2009). If, to produce, firms use polluting resources, it is crucial to know how environmental policy affects economic growth (and consumption levels). The approach to this problem has differed among studies. Authors who include pollution often consider polluting resources as necessary but non-essential to production as they may be substituted by non-polluting resources or innovations (e.g., Bretschger and Smulders, 2007; Gradus and Smulders, 1993; Grimaud and Rougé, 2003). In particular, Bretschger and Smulders (2007) considered the possible substitution between polluting resources (energy) and non-polluting ones (labor and capital) but did not include the role of policy intervention in the harmonization of economic growth and the environment. Some models considered the role of innovation in overcoming resource scarcities, but modeled innovation as exogenous. In contrast, endogenous growth theory often ignored the contribution of natural resources to growth (Barbier, 1999). We consider two forms of technical change: final-goods producers run research activities to generate emission-reducing knowledge and resource firms run R&D to increase the variety of usable natural resources.

Authors who have found compatibility between a cleaner environment and economic growth commonly consider resource scarcity (e.g., Grimaud and Rougé, 2005; Schou, 2000, 2002). As Schou (2002) pointed out, if resources are scarce, in the long run the need to save them will necessarily reduce pollution. To avoid this problem we ignore resource scarcity exploring a new trail to match the economy and the environment. Implicitly we are assuming that the economy can extract as much resources as it needs to satisfy production.

Other authors study the relationship between economic growth and environmental quality, but do not include natural resources. In this case, we find, for example, Xapapadeas (2005) who found compatibility between a growing economy and a cleaner environment if some economic wealth was devoted to environmental protection or pollution abatement activities. In the same line, Gupta and Barman (2009) analyzed the problem in a dynamic perspective using an endogenous growth model. The authors focused on the interaction between public expenditure and environmental pollution when government allocated its tax revenue between pollution abatement and productive expenditure. They also examined the characteristic of the optimal fiscal policy in a dynamic perspective. Among other interesting findings, the article found no conflict between the social welfare maximizing solution and the growth rate maximizing solution in steady-state.

Finally, some authors consider a broader question, not only the relationship between economic growth and pollution, but the relationship between economic decisions and pollution dynamics. In this case, we find Saltari and Travaglini (2011) who analyze the effects of environmental policy on the value of the firm and investment decisions. These authors include pollution uncertainty and investment irreversibility and focus on two types of policy instruments: taxes on polluting inputs and subsidies to reduce the costs of abatement capital. They found that an increase in the tax may decrease the value of the firm and therefore decrease investment in abatement capital. The effect of the subsidy on the firm's value is undetermined.

The remainder of the paper is organized as follows. Section 2 presents the model set-up. Section 3 shows the market equilibrium conditions in the balanced growth path, highlighting its major properties. Section 4 sums up the environmental policy implications. Section 5 characterizes the optimum. Section 6 performs a numerical exercise. Finally, Section 7 concludes the paper.

2. Model set-up

We consider a model in continuous time with differentiated final-goods, and a natural resource sector. In this section we present the several sectors.

2.1. Final-goods producers

The differentiated final-goods are produced by an exogenous number of firms ($n = 1,\ldots,N$). These goods are sold in imperfectly competitive markets and produced using natural resources, R:

$$Y_{n,t} = A\sum_{j=1}^{J} R_{j,n,t} \tag{1}$$

where t represents the time, $Y_{n,t}$ is the output of firm n, J is the number of usable resources varieties, $R_{j,n,t}$ is the amount of the jth type of natural resources used by firm n, $A > 1$ represents the overall productivity or efficiency of the economy.

Final-good producers run indoor research activities to generate pollution-reducing knowledge, Z. As in GT, the knowledge stock at each time is composed by a continuum of pieces. A piece of knowledge is an indivisible, infinitely-lived, differentiated, public good. In this specific case it refers to techniques which allow having less pollution for a given level of resources consumed, for instance, carbon capture and sequestration technologies or new production processes.

Each firm spends $\zeta_{n,t}$ units of its own output to produce new pieces of knowledge. $Z_{n,t}$ is the knowledge stock of firm n at time t.[2] New pieces of knowledge are produced with the technology:

$$\dot{Z}_{n,t} = \delta\zeta_{n,t} \tag{2}$$

where $\delta > 0$ is a productivity parameter. This knowledge accumulation function implies that the more firms spend on research activities, the more knowledge they generate (e.g., Buonanno et al., 2003; Goulder and Schneider, 1999).

Knowledge is used to reduce pollution (e.g., Bovenberg and Smulders, 1995; Grimaud and Rougé, 2003; GT). The emissions flow is:

$$E_{n,t} = \sum_{j=1}^{J} R_{j,n,t} Z_t^{-\beta} \tag{3}$$

where $\beta > 0$ measures the efficiency of knowledge to reduce pollution. Emissions increase with natural resources consumption (e.g., Bovenberg and Smulders, 1995; Schou, 2002), since it is the fossil fuels combustion and mineral resources use that generates most emissions/pollution in the production process. We treat emissions as a flow instead of a stock. In reality, many environmental issues last for several decades, but by considering pollution as a flow we simplify the analysis and reach similar results as we do treating emissions as a stock (e.g., Gradus and Smulders, 1993; Stokey, 1998).[3]

[2] Several models consider research conducted using only labor (e.g., Grimaud and Rougé, 2003, 2005; Schou, 2002). In line with lab-equipment growth models (e.g., Rivera-Batiz and Romer, 1991), we modify this view by considering firms spending a given amount of resources to conduct research.

[3] For a deeper discussion of this issue see, for example, GT and (Grimaud and Rougé, 2005).

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