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ANALYSIS

Economic development and environmental quality: A reassessment in light of nature's self-regeneration capacity☆

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ABSTRACT

We study the relationship between economic development and consumption of natural resources using a vintage capital model. Consumption of natural resources is assumed to generate pollution, part of which will be absorbed by nature's self-regeneration capacity. We find that during the transition dynamics, the shape of the pollution output relationship will depend on the parameter determining nature's self-regeneration capacity. Using footprint and biological capacity data, we show empirically in a repeated cross-section of countries that the shape of the pollution–output relationship indeed depends on countries' capacity to regenerate part of the resources they consume from nature.

1. Introduction

In October 2006 several newspapers announced that the earth had reached its *ecological debt day/overshoot day*.[1] This concept, which was first suggested by the Global Footprint Network (www.footprintnetwork.org) refers to the day in a year when humanity has consumed what nature can renew. In other words, if more wood is consumed than trees grow back, or fishery resources are depleted faster than spawn, then humanity has to dip into its stocks of natural capital. It is arguably then the tradeoff between the depletion of resources and the ability to regenerate these that is at the heart of the sustainability of countries' consumption habits. In other words, countries should be assessed not only in terms of the extent of pollution of the environment, but also with regard to their contribution in terms of rebuilding natural capital. This could then, for instance, be used to more accurately separate net debtors to the environment from net creditors, and hence allocate polluting rights accordingly.[2]

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[1] In 2006, the World Overshoot Day has been estimated to have occurred on October 9th (see http://www.neweconomics.org).

[2] A decade ago, Costanza et al. (1997), for the first time, provided a monetary figure of the goods and services our earth's ecosystem is providing. More specifically, they came up with an annual average value of $33trillion. A considerable amount of comments had spurred in the wake of this study, and eventually led to an increased interest in improving and refining the understanding of the quantity of resources the world can sustainably provide in the long run.

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Unfortunately academic studies generally have tended to disregard nature's regenerating ability when it comes to taking account of a country's contribution to polluting the environment, in part due to data availability. This is obvious, for instance, in the numerous studies that have tried to relate economic development to environmental pollution in what has come to be known as the Environmental Kuznets Curve (EKC), where pollution is often proxied by emissions of a particular pollutant, such as carbon dioxide or sulfur. In contrast, the recent footprint approach,[3] has not only taken important steps to synthesizing many measures of environmental degradation into a single proxy, but also managed to net out a country's ability to regenerate nature (which is usually referred to as biological capacity or biocapacity).

From a theoretical perspective, most studies coping with the issue of the relationship between economic development and environmental quality are constructed as if pollution were just another input in the production function, and ignore the possibility that different countries may be endowed with varying capacities to absorb pollution; see, for instance, Stokey's (1998) fundamental contribution to the theoretical modelling of the EKC. A notable exception in this regard is Aghion and Howitt (1998, chap. 5), who introduce a potential rate of regeneration in their environmental quality equation, thus avoiding pollution just to be the inverse of environmental quality.

In the present paper we use a theoretical framework enabling us to take account of nature's regeneration capacity in investigating the relationship between economic development and pollution. More specifically, we first construct a vintage capital model in which we, as do Aghion and Howitt (1998), incorporate the hypothesis that environmental quality is bound between some upper and a lower threshold, the latter one corresponding to a total collapse of nature. This allows us to endogenously model a turning point in the pollution–output relationship, as has been highlighted in the EKC literature. Traditionally, the EKC literature has attributed the existence of the pollution–output relationship, and its possible non-linearity, to three factors: a scale effect (i.e., as economies grow, pollution grows proportionally), a technique effect (i.e., if environmental quality is a normal good, nations may use less pollution–intensive techniques of production), and a composition effect (i.e., pollution may decrease or increase with income, according to which goods are produced and traded in a country). Our framework allows us to tackle the two former explanations of the EKC. As production increases, pollution, which will depend on the quantity of inputs, will augment (scale effect). However, as is standard in vintage capital models, obsolete machines will be replaced by less pollution–intensive techniques (technique effect). The overall effect will depend on the interplay of these two factors. The composition effect is not addressed here since we model a closed economy, producing one type of good.

Vintage capital models are arguably particularly useful to analyzing issues related to sustainability as they allow to endogenously integrate the optimal timing of adoption of a more environmental friendly technology. In using this modelling strategy, we can then easily show the discrepancies that may arise when ignoring nature's potential regeneration ability. In particular, our results show that if there is a bell-shaped relationship between economic development and environmental quality, the peak of the curve will be reached for smaller values of output per capita when one considers some general measure of pollution net of self-regeneration rather than only pollution.

Using newly constructed cross-country, time-varying footprint data that allow the distinction between gross and net demand on the environment, we then empirically put the predictions of our theoretical model to the test. Our empirical results are indeed found to be in line with the theoretical findings. More specifically, the maximum of the environmental degradation–economic development relationship is reached for larger values when one does not take into account nature's self-regeneration capacity compared to when this aspect is incorporated in the measure of degradation. Moreover, we find that the upward sloping part of the curve is steeper when regeneration is neglected. These results arguably have potentially important policy implications in that they suggest that failing to account for countries' regeneration capacity may bias the effort required to maintain a sustainable development. Put differently, if pollution generation has to be evaluated so as to attribute it a cost, so should nature's regeneration capacity.

The rest of the paper is organized as follows. Our vintage capital model is presented in Section 2. Section 3 contains a description of our data, the empirical framework, and the econometric results. Concluding remarks are provided in Section 4.

2. The model

In this section, we first present a standard vintage capital model, where we add an equation of motion representing environmental quality. Vintage capital models formalize Schumpeter's idea of "creative destruction", and have been applied to different issues related to economic development (see Aghion and Howitt, 1998). In the present context, our theoretical framework will introduce a vintage capital structure in the Aghion and Howitt (1998) framework, where the law of motion of environmental quality will depend on the pollution flow and some upper limit on environmental quality that takes into account the exhaustibility of resources (Bertinelli et al., 2005). Our model is particularly appropriate to tackle issues related to sustainable economic development, as it allows the endogenous determination of the optimal period of adoption of newer, potentially cleaner, technologies.

2.1. A vintage capital structure

We consider an economy where the labor market is perfectly competitive, and the production sector produces only one final good, assigned either to consumption or investment, and plays the role of the numeraire. Furthermore, the population level is assumed to be constant.

2.1.1. Production

At time $t>0$, output per capita $y(t)$ is assumed to follow a vintage capital rule

$$y(t) = \int_{t-T(t)}^{t} i(z)dz. \tag{1}$$

[3] Footprint measures synthesize consumption of natural resources, using a common value, i.e., the standardized area of land needed to regenerate these resources. A detailed account of footprint is provided in Section 3.