ECOLOGICAL ECONOMICS 63 (2007) 54–58

available at www.sciencedirect.com

ScienceDirect

www.elsevier.com/locate/ecolecon

ANALYSIS

Total factor productivity and the Environmental Kuznets Curve: A comment and some intuition

*Neha Khanna**, *Florenz Plassmann*[1]

Department of Economics, Binghamton University, P.O. Box 6000, Binghamton, NY 13902–6000, USA

ARTICLE INFO

Article history:
Received 3 May 2006
Received in revised form
22 September 2006
Accepted 23 September 2006
Available online 6 December 2006

Keywords:
Abatement
Environmental quality
Pollution
Marginal rate of substitution
Marginal rate of transformation

JEL classification:
Q50; Q56

ABSTRACT

Chimeli and Braden [Chimeli, Ariaster B., Braden, John B., 2005. Total factor productivity and the Environmental Kuznets Curve. Journal of Environmental Economics and Management 49, 366–380] derive a necessary and sufficient condition under which inter-country differences in total factor productivity can yield an Environmental Kuznets Curve. They argue that their results emphasize the importance of differences in total factor productivity across countries as well as the need for decreasing returns to scale in pollution-abating technologies for the existence of an Environmental Kuznets Curve. We show that their Proposition 1 is equivalent to Proposition 2 in Lieb [Lieb, Christoph M., 2002. The Environmental Kuznets Curve and satiation: a simple static model. Environment and Development Economics 7, 429–448]. This implies that, even in Chimeli and Braden's model, contemporaneous changes in the marginal rate of substitution between environmental quality and consumption on the demand side and the marginal rate of transformation between these goods on the supply side drive the pollution–income relationship. This is a very general condition that does not rely on either differences in total factor productivity or decreasing returns to scale in abatement, and which is widely applicable.

1. Introduction

Chimeli and Braden (2005) show that differences in total factor productivity can yield a U-shaped relationship between environmental quality and income in a cross section of countries, a relationship implied by the Environmental Kuznets Curve (EKC) hypothesis. Several authors have empirically tested the EKC hypothesis using either cross-sectional data (for example Gawande et al., 2000; Khanna and Plassmann, 2004) or data that cover a relatively short time period (for example, Torras and Boyce, 1998), and Chimeli and Braden's result provides a theoretical justification for these tests.

In their Proposition 1, Chimeli and Braden derive a condition that is necessary and sufficient for a cross-sectional EKC under their model assumptions. This condition is fairly complex, and they offer only a narrow explanation for their result that emphasizes differences in total factor productivity across countries as well as the need for decreasing returns to scale in pollution-abating technologies. We show that their necessary and sufficient condition is equivalent to Proposition 2 in Lieb (2002). We use this equivalence to derive an economically appealing and general interpretation for Chimeli and Braden's result: that the existence of an EKC simply depends on appropriate joint changes in the marginal rates of substitution and transformation and differences in income or resources, regardless of what the source of those differences might be.

In the following section, we provide a brief outline of both models. We retain the original notations as far as possible for

* *Corresponding author*. Tel.: +1 607 777 2689; fax: +1 607 777 2681.
E-mail addresses: nkhanna@bux2k.binghamton.edu (N. Khanna), fplass@binghamton.edu (F. Plassmann).
[1] Tel.: +1 607 777 4304; fax: +1 607 777 2681.

0921-8009/$ - see front matter © 2006 Elsevier B.V. All rights reserved.
doi:10.1016/j.ecolecon.2006.09.020

the sake of comparability with the original papers, but we compare and contrast the notations to emphasize a few subtle differences in the setup of the two models. We establish the equivalence of the two propositions in Section 3, and provide the economic intuition for Chimeli and Braden's result in Section 4.

2. The models

2.1. Chimeli and Braden (2005) (henceforth C&B)

Individual utility, u, is determined by the flow of per capita consumption, c, and the stock of environmental quality, E, and it is maximized subject to the equations of motion for E and the capital stock, K. Both E and c are economic goods, so that $u_E>0$, $u_c>0$. Environmental quality decreases with gross anthropogenic pollution, P, and improves with pollution abatement, Π, which is a non-linear function of environmental protection effort, π.[2] A social planner maximizes the present value of social welfare over an infinite time horizon. The economy's output, F, is divided between aggregate consumption, environmental protection, and capital accumulation. The model is closed by specifying initial values for E and K. The social planner's problem is described formally as:

$$\max_{c,\pi} \int_0^\infty e^{-\rho t} N u(c,E)\,dt \tag{1}$$
$$\text{subject to}$$
$$\dot{E} = -P(K) + \Pi(\pi)$$
$$\dot{K} = F(K) - Nc - \pi$$
$$E, K, c, \pi \geq 0$$
$$E(0) = E_0, K(0) = K_0,$$

where $\rho>0$ is the discount rate and N is the population size.[3] C&B specify assumptions about the curvature of the utility, gross pollution, output, and abatement functions to obtain a unique and interior solution to the social planner's problem. Because this is an infinite horizon model, they evaluate the comparative statics that yield an EKC for a cross section of economies at the steady state. It is in this context that their analysis is conceptually equivalent to the static, representative agent model developed by Lieb (2002); see also Weitzman, (2003), pp. 19–25, which, in turn, is a more general version of McConnell (1997) and Stokey (1998).

2.2. Lieb (2002) (henceforth Lieb)

Individual utility, U, is a function of consumption, C, and net anthropogenic pollution, P. Consumption is an economic good and net pollution is an economic 'bad', so that $U_C>0$, $U_P<0$. Net pollution increases with C and decreases with abatement expenditures, A. Outlays on consumption and abatement come directly from the economy's endowment of resources, Y. Thus the representative agent's problem is

$$\max_{C,A} U(C,P) \tag{2}$$
$$\text{subject to}$$
$$P = P(C,A)$$
$$Y = C + A$$
$$A \geq 0, P \geq 0.$$

Lieb makes additional assumptions regarding the slope and curvature of the net pollution function ($P_C>0$, $P_A<0$, $P_{CC}\geq 0$, $P_{AA}>0$, and $P_{CA}=P_{AC}\leq 0$), which imply that the consumption possibilities curve between C and P (which is defined by the net pollution function for given Y) is strictly convex.

2.3. Note the notation

The notation and terminology used in these two papers is sufficiently similar to obscure differences between the two models. We outline some of the main differences and potential sources of confusion. First, Lieb defines P as net pollution (gross pollution less abatement), whereas C&B define P as gross pollution. Second, Lieb's net pollution P is equivalent to the negative of C&B's environmental quality E, under the assumption that environmental quality is the difference between the pristine state of the environment, O, and anthropogenic net pollution, and O is normalized to zero. Third, Lieb's abatement expenditure, A, is the same as C&B's π. Fourth, C&B model pollution abatement, Π, as a function of π, and there is no equivalent to Π in Lieb (but that is irrelevant for our purposes). Finally, C&B use the variable A to denote total factor productivity. In a cross section of economies in steady state, differences in A across countries describe differences in output. So dA represents a change in steady state output and is therefore equivalent to dY in Lieb.

3. The equivalence between C&B's Proposition 1 and Lieb's Proposition 2

3.1. Lieb

Net pollution P is a function of consumption C and abatement A, so that $\frac{\partial P}{\partial C} = P_C = P_C(C, A)$ and $\frac{\partial P}{\partial A} = P_A = P_A(C, A)$, and therefore $dP_C = P_{CC}dC + P_{CA}dA$ and $dP_A = P_{AC}dC + P_{AA}dA$. Dividing the two total derivatives by dC and evaluating them at $dP=0$ yields

$$\left.\frac{dP_C}{dC}\right|_{dP=0} = P_{CC} + P_{CA}\left.\frac{dA}{dC}\right|_{dP=0} = V$$

and

$$\left.\frac{dP_A}{dC}\right|_{dP=0} = P_{AC} + P_{AA}\left.\frac{dA}{dC}\right|_{dP=0} = W.$$

[2] To be consistent with C&B, we use the term pollution abatement in the broadest sense so that it includes not only pollution reduction and prevention, but also recovery as well as the direct generation of environmental quality through the creation of nature preserves, species protection, etc.

[3] This is a generalized version of Problem 9 in Weitzman (2003, see pp. 56–60 and 173–181).