A New Approach to Pollution Modelling in Models of the Environmental Kuznets Curve

Hannes Egli*

JEL Classification: Q2, Q5
Keywords: Environmental Kuznets Curve, negative pollution, abatement technology, increasing returns to scale

1. Introduction

Knowledge about the relationship between environmental pollution and income is decisive for reliable predictions of long-term development of individual welfare. If the pollution-income relation is characterised by the eventual decoupling of pollution from economic growth, then sustained growth without excess pollution could be feasible. If, on the other hand, economic growth invariably comes with increasing environmental degradation, the growth potential could be limited, as propagated by the Club of Rome (Meadows, Meadows, Randers and Behrens, 1972).

The Environmental Kuznets Curve (EKC) is one of the most-used concepts to analyse the pollution-income relation. EKC models largely dominate both the empirical and theoretical literature on economic growth and pollution. The theoretical literature on EKCs can be separated into two major strands. The first class of models stresses shifts in the production technologies, which differ in their pollution intensity, as the main cause for the hump-shaped pollution-income relation. Prominent examples of this strand are the contributions of Stokey (1998) and Smulders and Bretschger (2000). In the second class, the inverted U-shaped pollution-income relation results from the explicitly modelled abatement of (gross) pollution. That is, besides consumption and investments in accumulable (human or physical) capital, there is an additional

* ETH Zurich, Institute of Economic Research, Zürichbergstrasse 18, ZUE F 10, CH-8032 Zurich, Switzerland. Email: hegli@ethz.ch. The author thanks Lucas Bretschger, Christa Brunnschweiler, Karen Pittel and Thomas M. Steger for helpful comments and suggestions.

economic activity, namely environmental effort. The characteristics of the abatement technology are crucial for the occurrence of an EKC. Examples for this strand of EKC models are JOHN and PECCHENINO (1994), SELDEN and SONG (1995), ANDREONI and LEVINSON (2001), BROCK and TAYLOR (2004) and EGLI and STEGER (2005).[1]

The focus of this paper lies on EKC models of the second class and, in particular, on models where net pollution is defined as the difference between gross pollution and abatement. The main characteristic necessary to generate an EKC is a form of increasing returns to scale (IRS) in the abatement technology (see ANDREONI and LEVINSON, 2001). But assuming IRS in abatement only leads to reasonable implications in the short and medium run. In the long run, this specific model set-up often results in unrealistic implications. Pollution both as a stock and as a flow variable can become negative as soon as the whole stock of pollution – if there is any at all – has been abated and the actual output of the "abatement sector", i.e. abated pollution, is greater than the amount of pollution generated by the polluting activities. This, of course, is an incorrect prediction. In order to diminish environmental degradation, there must be a positive amount of pollution in the first place – at least from a logical point of view. As a result, negative net pollution flows can only be justified as long as there is a positive pollution stock. It should be noted that the problem of negative pollution arises with or without the incorporation of a pollution stock. In the former case, the problem is less severe since temporarily negative pollution flows can be justified and typically arises at a later date.

The potential occurrence of negative pollution is, however, not only a technical problem, which could be solved by appropriate constraints, but has severe consequences. Specifically, even the reliability of the predictions for the short and medium run are challenged. If a model implies implausible or incorrect predictions for the long run, the model specification does apparently not reflect real economic relations or the facts observed by the natural sciences.

Up to now, the problem of negative pollution has not been adequately addressed in the theoretical EKC literature. Therefore, the hitherto existing predictions might not be optimal or reliable. The present paper tries to close this gap. In a first step, it critically discusses two approaches to avoiding negative pollution,

1 DE GROOT (1999) stresses structural changes within an economy as the main cause for an EKC. However, the underlying mechanism is largely restricted to developing countries and does not apply in the same way to mature economies. As a result, this mechanism has not attracted considerable attention in the EKC literature.

which are adopted in existing EKC models. These are, first, the restriction to interior solutions, i.e. only that period of time or development phase is considered where pollution is positive. Second, the original modelling with net pollution as the difference between gross pollution and abatement is converted into a specification in line with pollution intensities. Since intensities are non-negative by definition, pollution will be non-negative as well. In a second step, a new approach for modelling pollution in EKC models with abatement is introduced. It is argued that the assumption of perpetual increasing returns to scale in abatement is debatable. In consequence, the main mechanism of the proposed approach lies in a continuous restraint of the degree of the IRS in the abatement sector. With an appropriate functional specification of the model, pollution stocks and flows remain strictly positive.

The remainder of this paper is organised as follows. The first step, i.e. the discussion of the existing approaches to avoid negative pollution, is dealt with in Sections 2 (restriction to interior solutions) and 3 (conversion of the pollution function with explicit gross pollution and abatement functions into a specification with a pollution intensity). The subsequent two sections address the second step. In Section 4, the evidence on economies of scale in abatement is discussed. Section 5 deals with the new approach of fading increasing returns to scale in abatement. Finally, Section 6 concludes.

2. Interior Solutions and Non-Negativity Constraint

In most theoretical EKC models, the hump-shaped pollution-income relation occurs at early stages of economic development. That is, pollution rises right from the start, until eventually a decoupling of environmental degradation from economic growth occurs. The problem of negative pollution – as a flow or as a stock variable – emerges relatively late in the development process, after abatement has succeeded in reducing pollution to zero. On account of this chronology, some models ignore the possibility of negative pollution and make do with the proof of an inverted U-shaped pollution-income relation or turn the attention to interior solutions only (e.g. Selden and Song, 1995). By disregarding the eventuality of negative pollution and the associated unrealistic implications, these procedures are not fully satisfying despite their simplicity and manageability.

The first approach to avoiding negative pollution is a purely technical solution. Specifically, the model under consideration is augmented by a non-negativity constraint for pollution. As an illustration, consider the following net pollution function known from literature:[2]

$$P(C,E)=A[C-B(C,E)], \tag{1}$$

where P is net pollution, C consumption, E environmental effort, A a pollution intensity parameter reflecting the actual state of the technological knowledge and $B(\cdot)$ is the abatement technology. Gross pollution, reflected by the first term in brackets, is a linear function of the polluting economic activity, namely consumption.[3] ANDREONI and LEVINSON (2001) show that with a linear gross pollution function, increasing returns to scale in abatement is a necessary condition for an EKC pattern. The non-negativity constraint for pollution then requires:

$$P(C,E)\geq 0. \tag{2}$$

Provided that both C and E grow over time and that abatement is characterised by IRS, net pollution [equation (1)] would eventually become negative. Hence, equation (2) becomes binding sooner or later. In order to satisfy the non-negativity constraint, consumption and environmental effort can no longer be chosen independently. In fact, for $P=0$ environmental effort is no longer an independent choice variable but rather a function of consumption.

The consideration of a non-negativity constraint for pollution does not constitute a satisfying solution for the problem of negative pollution. The prevention of negative pollution is of a solely technical nature and not due to a more realistic abatement function. Thus, the reservations about pollution functions implying negative pollution in the long run still apply. Moreover, both consumption and environmental effort are discontinuous at the point in time where the non-negativity constraint becomes binding. The empirical plausibility of such discontinuities is questionable.

2 To simplify notation, the time index is suppressed.

3 More frequently, pollution is modelled as a by-product of production (e.g. XEPAPADEAS, 2004). However, the assumption that only part of the production is polluting is warrantable as well (JOHN and PECCHENINO, 1994).

3. From Abatement to Pollution Intensities

Since the potential occurrence of negative pollution can be traced back inter alia to the modelling of net pollution as the difference between gross pollution and abatement, the second approach to avoiding negative pollution starts at this point. Specifically, the idea is to convert the original specification with explicit gross pollution and abatement functions into a specification, where net pollution is given by the product of the polluting economic activity and a measurement for environmental effort (see e.g. the *Green Solow Model* of Brock and Taylor, 2004). One could argue that this procedure, i.e. the pooling of the gross pollution and abatement functions, corresponds to a specification characterised by pollution intensities. In other words, the mechanism employed by the other prevailing class of theoretical EKC models (see Section 1) is adopted.

For an illustration of this procedure, consider the same net pollution function as in Section 2 [equation (1)]. Assuming – as Brock and Taylor (2004) – that $B(\cdot)$ is linearly homogeneous and defining $h = E/C$, the pollution function can be rewritten as:

$$P(C,E) = AC[1 - B(1,h)], \tag{3}$$

respectively as:

$$P = ACb(h) \;\text{ where }\; b(h) = [1 - B(1,h)], \tag{4}$$

where $b(h)$ can be regarded as an abatement function in intensive form depending on the ratio of (polluting) consumption and environmental effort. However, rewriting equation (1) with a pollution intensity term is not a remedy for negative pollution. The success of this approach lies rather in the adequate choice of the functional form of the abatement function in intensive form. For plausibility reasons, environmental effort should have a positive but decreasing marginal effect on pollution reduction, i.e. the following conditions should hold: $b(0) = 1$, $b'(h) < 0$ and $b''(h) > 0$. To prevent pollution from becoming negative, $b(h)$ must additionally satisfy

$$\lim_{h \to \infty} b(h) \geq 0. \tag{5}$$

Otherwise, the non-negativity of pollution is not guaranteed. Provided that $C > E$ and, hence, $0 \leq h \leq 1$ the following functional form could be employed:

$$b(h) = (1-h)^{\varepsilon} \quad \text{with} \quad \varepsilon > 1 \tag{6}$$

This function has the desired attributes and satisfies the condition for non-negative pollution.[4] Even if the same amount were be spent for abatement as for consumption, pollution would simply be equal to zero but never become negative. However, if h were constant or bounded from above with an upper bound smaller than unity, there would have to be technological progress targeted at more environmentally friendly production technologies (thereby reducing the intensity parameter A) in order to get a pollution-income relation in line with the EKC.

At first glance, the procedure outlined in this section seems to be a solution to avoid negative pollution. At closer inspection, however, it becomes clear that its success depends on the accurate specification of the abatement function in intensive form [$b(h)$]. In addition, technological progress could possibly be necessary for an EKC-type pollution-income relation.

4. Evidence on Returns in Abatement

As pointed out in Section 1, many EKC models are based on a form of scale economies, which can be due to direct modelling or due to fixed costs.[5] By explicitly modelling an abatement technology, ANDREONI and LEVINSON (2001) demonstrate that IRS in abatement are crucial for the occurrence of an EKC pattern. This applies provided that the gross pollution function is linear. In a more general version of the ANDREONI and LEVINSON (2001) model, PLASSMANN and KHANNA (2004, p. 16) show that *"for non-constant returns to scale in gross pollution, a sufficient condition for pollution to decline is rather that the returns to scale in abatement exceed the returns to scale in gross pollution."* Formally, assume that the abatement function $B(C,E)$ is homogeneous of degree d and the gross pollution

4 Equation (6) is adopted from BROCK and TAYLOR (2004). In their model, production and not only consumption is polluting. Hence, h is defined as the fraction of overall economic activity dedicated to abatement and $0 \leq h \leq 1$ is fulfilled by definition.

5 Fixed costs are conceivable for example in pollution abatement. As a result, poorer countries use dirtier production technologies, as in STOKEY (1998), or there is a zero-abatement phase at the beginning, as in SELDEN and SONG (1995). Another example for fixed costs is given by appointment costs of institutions which stick up for the environment, e.g. an environmental protection agency (JONES and MANUELLI, 2001). Hence, richer countries are more likely to have powerful environmental institutions.

function $G(C)$ is homogeneous of degree θd. Then, a sufficient condition of an EKC pattern is $\theta < 1$.[6]

However, if pollution is considered in terms of emissions – as opposed to in terms of ambient concentration or in terms of damage – the assumption of a linear gross pollution function is most appropriate. In this paper, the focus lies on pollution as a flow variable and, hence, pollution should be best regarded in terms of emissions. Thus, the leading cause for the occurrence of negative pollution is the assumption of IRS in abatement. On this occasion, the question of the plausibility of increasing returns to scale in abatement arises. Is the pervasive existence of IRS indeed an appropriate assumption? Or is abatement rather characterised by fading increasing returns to scale? On the one hand, Andreoni and Levinson (2001, pp. 278–281) report empirical evidence of IRS in abatement. For example, at the plant level, the costs of controlling emissions of large coal-fired boilers decline substantially with the boiler size. At the level of US states, the authors show that *"average pollution abatement costs per dollar of GSP [gross state product] decline with industry size, across states and industries, and over time."* Moreover, Maradan and Vassiliev (2005) report that the marginal opportunity costs of carbon dioxide abatement, measured as forgone production of output, are negatively associated with income. All these empirical findings can be interpreted as evidence for the existence of IRS in abatement.

On the other hand, there are also legitimate arguments for fading IRS in abatement. First, it is not clear from the outset that doubling both pollution and environmental effort results throughout in more than doubled abated pollution. In contrast, it seems plausible that abating pollution becomes relatively more resource intensive as the last speck of pollution is or must be tackled. Second, abatement activities may be characterised by learning by doing, so that experience in pollution abatement will indeed increase the effectiveness of environmental effort. However, learning curves typically show that the potential gains due to experience decrease with the cumulative activity. Moreover, the potential cost reductions associated with learning are usually higher for infant technologies than for mature technologies (Bramoullé and Olson, 2005). There are no broad empirical estimates of learning curves for pollution abatement so far. The early study of Bellas (1998) can be regarded as an exception. He finds a decreasing cost trend of flue gas desulphurisation units over their lifetimes. Despite the fact that this result can be regarded as evidence for the existence of

6 A technical proof is given by Plassman and Khanna (2004, pp. 6–15). The pollution function (1) with IRS in abatement is compatible with this notation if $\theta = 1/d$ and $d > 1$.

learning-by-doing effects, no conclusions regarding decreasing learning effects can be drawn by means of this study. Yet, McDONALD and SCHRATTENHOLZER (2001) compile estimated learning rates for various energy technologies from 26 field studies, and conclude that later data imply lower learning rates, especially for gas turbines and gas turbine combined-cycle power plants.

In sum, there is evidence for the existence of increasing returns to scale in abatement. In addition, it seems more plausible that an abatement technology can indeed exhibit IRS at some stages but not throughout. In other words, with rising environmental effort, the increasing returns to scale in abatement level off.

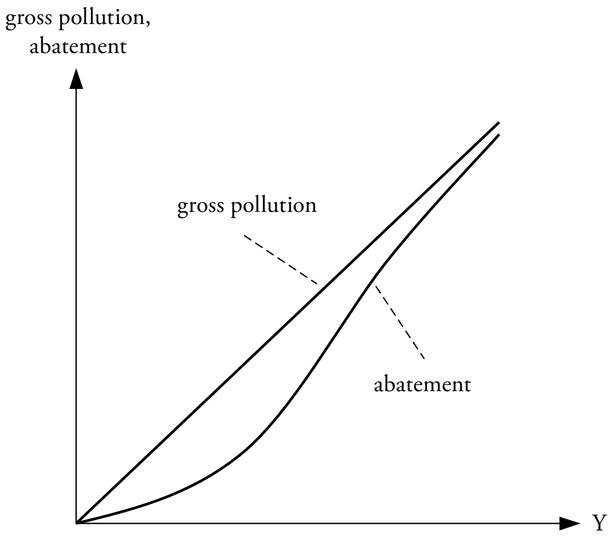
5. New Approach: Fading IRS in Abatement

5.1. The General Mechanism

On the basis of the arguments above, a further mechanism to avoid negative pollution becomes obvious: continuous restraint of the degree of the increasing returns to scale. In other words, at the beginning the abatement technology exhibits increasing returns to scale. But with rising abatement activities the IRS get weaker and weaker and approach constant returns to scale (CRS) in the limit. This general mechanism is illustrated in Figure 1. The gross pollution function is linear in the polluting activity, while the abatement technology exhibits IRS at the beginning but eventually becomes a linear function too. If the restraint of the degree of IRS is adequately specified, an EKC-conform pollution-income relation would still result, but pollution would never become negative. Pollution would rather approach a non-negative constant.

This procedure does not only constitute a accurate solution to the theoretical problem of negative pollution, but also does well regarding the empirical plausibility of the abatement technology. Moreover, its smooth decline of pollution is more plausible than a steep decline and an abrupt change from positive pollution levels to zero pollution, as would result with the incorporation of a non-negativity constraint for pollution. However, it should be noted that this approach is only applicable to EKC models with explicitly modelled increasing returns to scale in the abatement technology.

Figure 1: Fading IRS in Abatement



5.2. A Specific Example

To further illustrated this approach, the fading-IRS mechanism is now applied to a dynamic EKC model with a net pollution function in line with equation (1). However, the abatement technology is slightly modified. Basically, $B(C,E)$ exhibits IRS but the degree of the IRS steadily declines with increasing environmental effort E. In the limit, $B(C,E)$ is approximately characterised by CRS. The following net pollution function fulfills this property:

$$P = C - C^{\alpha} E^{1-\alpha+\frac{1}{1+E^2}} \tag{7}$$

The decreasing degree of IRS is due to the second term in the exponent of E, i.e. $1/(1 + E^2)$, which approaches zero as E becomes large. Of the various arguments for fading IRS in abatement (outlined in Section 4 above), the declining learning effects fit best with this particular specification, since it is E and not e.g. P which causes the continuous restraint of the degree of IRS in equation (7).

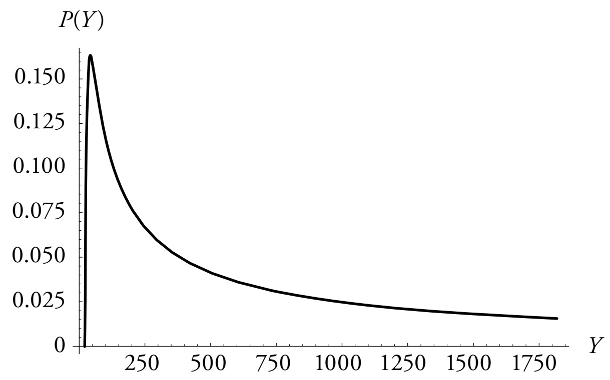
Assuming for illustration purposes that $\alpha = 0.5$, consumption and environmental effort will be approximately equal in the long run. As a result, net pollution approaches zero. It should be noted that the condition $\alpha = 0.5$ for net pollution to be zero with CRS is not a singularity of this specification, but is also valid for the seminal ANDREONI and LEVINSON (2001) model. With CRS and $\alpha > 0.5$, net pollution is monotonically increasing, whereas with CRS and $\alpha < 0.5$, net pollution is monotonically decreasing and, thus, would eventually become negative.

A numerical example with the above net pollution function is provided in Figure 2. The illustration is based on an optimisation of the utility function

$$\int_0^\infty [\log(C - zP)] e^{-\rho t} \, dt$$

subject to a standard capital accumulation equation $K = DK - \delta K - C - E$, where z reflects the desire for a clean environment, ρ denotes time preference, P is net pollution according to equation (7), K is capital, D a constant technology parameter and δ the capital depreciation rate.[7]

Figure 2: Pollution-income Relation with Fading IRS in Abatement

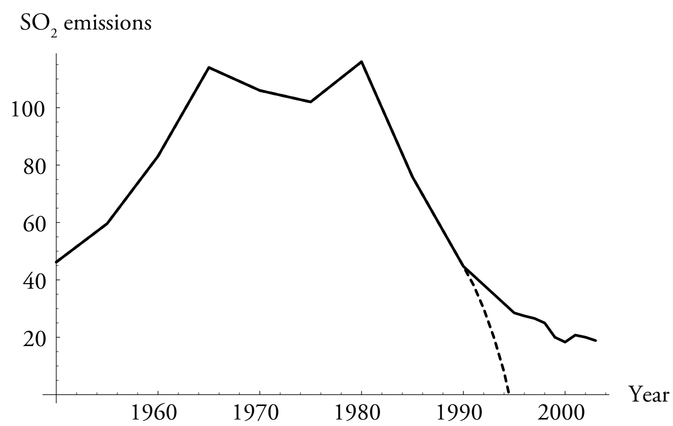


7 The following set of parameters is employed: $D = 0.12$, $\delta = 0.06$, $\rho = 0.04$, $\alpha = 0.5$ and $z = 1$. The case $z = 1$ represents an interesting limiting case which is relevant in the sense that the qualitative results largely hold true also for $z < 1$. For a detailed parameter calibration and the consequences of $z < 1$ see EGLI and STEGER (2005, pp. 11–14).

For the relevant range of income the pollution-income relation plotted in Figure 2 has all "desired" characteristics: hump-shaped, asymmetric with an upper tail that declines relatively gradually and – most importantly – non-negative net pollution in the long run.[8] Thus, with an appropriate specification of the net pollution function, the approach with fading IRS in abatement constitutes a promising way of modelling pollution in EKC models with explicit abatement technologies. Unlike e.g. the purely technical solution with a non-negativity constraint (Section 2), the approach outlined in this section is able to reflect the real economic relations and the facts observed by the natural sciences.

For example, consider the actual SO_2 emissions for Switzerland for the years 1950–2003 reported in Figure 3. Since 1980, the SO_2 emissions have been steadily decreasing. However, the rate of decline is not constant. After 1990 the reductions slowed down. Such an emission path is compatible with the argument of fading increasing returns to scale, but not with constant IRS in abatement. With constant IRS in abatement, the emission path would rather continue like the dashed line in Figure 3.

Figure 3: SO_2 Emissions for Switzerland, 1950–2003



Note: SO_2 emissions in Gg.
Source: 1950–1989: *SAEFL* (1995); 1990–2003; *SAEFL, current data, Swiss Agency for the Environment, Forests and Landscape.*

8 According to empirical evidence reported by Grossman and Krueger (1995) the pollution-income relation should be skewed to the right.

6. Summary and Conclusions

Theoretical EKC models with an explicit abatement technology and net pollution as the difference between gross pollution and abatement, often involve that both pollution as a stock variable and pollution as a flow variable can potentially become negative.

In the theoretical literature on the Environmental Kuznets Curve the aspect of negative pollution is usually not adequately addressed. The paper at hand has tried to close this gap. In a first step, two different solution approaches adopted in existing EKC models were discussed. First, the restriction to interior solutions and the consideration of an additional non-negativity constraint for pollution were investigated. It was argued that this procedure is not fully satisfying since it is of a solely technical nature and not due to a more realistic abatement function. Second, an approach employed by Brock and Taylor (2004) was discussed. By converting the original pollution function with net pollution as difference between gross pollution and abatement into a pollution function in line with emission intensities, these authors proposed a smart solution to the problem of negative pollution. However, this approach does not constitute a general solution but its success depends rather on the choice of the "right" functional form for the abatement technology, and in some circumstances additional technological progress is necessary for an hump-shaped pollution-income relation.

In a second step, a new approach to avoid negative pollution was introduced. Motivated by the debatable assumption of perpetual increasing returns to scale in abatement, the mechanism of fading IRS was proposed. By a continuous restraint of the IRS until the abatement technology exhibits CRS in the limit, the pollution-income relation can potentially be characterised by non-negative pollution levels in the long run. Even though this new approach is promising, it is not a panacea for the problem of negative pollution. The general applicability is not given since this mechanism can only be employed in EKC models with explicitly modelled IRS in abatement. Furthermore, more research on an appropriate functional specification generating the needed restraint of the degree of IRS is required.

References

Andreoni, James and Arik Levinson (2001), "The Simple Analytics of the Environmental Kuznets Curve", *Journal of Public Economics*, 80 (2), pp. 269–286.

Bellas, Allen S. (1998), "Empirical Evidence of Advances in Scrubber Technology", *Resource and Energy Economics*, 20 (4), pp. 327–343.

Bramoullé, Yann and Lars J. Olson (2005), "Allocation of Pollution Abatement under Learning by Doing", *Journal of Public Economics*, forthcoming.

Brock, William A. and M. Scott Taylor (2004), "The Green Solow Model", NBER Working Paper Series, No. 10557.

De Groot, Henri L. F. (1999), "Structural Change, Economic Growth and the Environmental Kuznets Curve. A Theoretical Perspective", OCFEB Research Memorandum 9911, Erasmus University Rotterdam.

Egli, Hannes and Thomas M. Steger (2005), "A Dynamic Model of the Environmental Kuznets Curve. Turning Point and Public Policy", Economics Working Paper Series 04/33, ETH Zurich.

Grossman, Gene M. and Alan B. Krueger (1995), "Economic Growth and the Environment", *Quarterly Journal of Economics*, 110 (2), pp. 353–377.

John, Andrew A. and Rowena A. Pecchenino (1994), "An Overlapping Generations Model of Growth and the Environment", *The Economic Journal*, 104 (427), pp. 1393–1410.

Jones, Larry E. and Rodolfo E. Manuelli (2001), "Endogenous Policy Choice: The Case of Pollution and Growth", *Review of Economic Dynamics*, 4 (2), pp. 369–405.

Maradan, David and Anatoli Vassiliev (2005), "Marginal Costs of Carbon Dioxide Abatement: Empirical Evidence from Cross-Country Analysis", *Swiss Journal of Economics and Statistics*, 141 (3), pp. 377–410.

McDonald, Alan and Leo Schrattenholzer (2001), "Learning Rates for Energy Technologies", *Energy Policy*, 29 (4), pp. 255–261.

Meadows, Donella H., Dennis L. Meadows, Jørgen Randers and William W. Behrens III (1972), *The Limits to Growth: A Report for The Club of Rome's Project on the Predicament of Mankind*, New York.

Plassmann, Florenz and Neha Khanna (2004), "A Note on 'The Simple Analytics of the Environmental Kuznets Curve'", Working Paper 0314, Binghamton University, Department of Economics.

Selden, Thomas M. and Daqing Song (1995), "Neoclassical Growth, the J Curve for Abatement, and the Inverted U Curve for Pollution", *Journal of Environmental Economics and Management*, 29 (2), pp. 162–168.

SMULDERS, SJAK and LUCAS BRETSCHGER (2000), "Explaining Environmental Kuznets Curves: How Pollution Induces Policy and New Technologies", Discussion Paper 12/00, Ernst-Moritz-Arndt University of Greifswald.

STOKEY, NANCY L. (1998), "Are there Limits to Growth?", *International Economic Review*, 39 (1), pp. 1–31.

SWISS AGENCY FOR THE ENVIRONMENT, FORESTS AND LANDSCAPE (1995), "Vom Menschen verursachte Luftschadstoff-Emissionen in der Schweiz von 1900 bis 2010", Schriftenreihe Umwelt, SRU-256-D.

XEPAPADEAS, ANASTASIOS (2004), "Economic Growth and the Environment", forthcoming in: Karl-Goran Mäler and Jeffery Vincent (eds.), *Handbook of Environmental Economics* (Volume 3), North-Holland.

SUMMARY

Models of the Environmental Kuznets Curve, particularly those with an explicit abatement technology, often involve that pollution becomes negative in the long run. This, of course, is a highly implausible prediction. The paper at hand examines the problem of negative pollution by, first, critically discussing two approaches adopted in existing EKC models and, second, by proposing a new approach. Motivated by the debatable assumption of perpetually increasing returns to scale in abatement, the idea of fading increasing returns to scale is introduced. This procedure does not only constitute a solution to the theoretical problem of negative pollution, but also does well regarding the empirical plausibility of the abatement technology.

ZUSAMMENFASSUNG

In Modellen zur Environmental Kuznets Curve, insbesondere in jenen mit einer expliziten Verschmutzungsabbautechnologie, wird die Verschmutzung in der langen Frist oft negativ. Dies ist natürlich eine höchst unwahrscheinliche Voraussage. Der vorliegende Beitrag untersucht das Problem der negativen Verschmutzung erstens durch eine kritische Diskussion zweier Ansätze, welche in existierenden EKC-Modellen verwendet werden, und zweitens durch die Präsentation eines neuen Ansatzes. Basierend auf der fragwürdigen Annahme von steigenden Skalenerträgen im Verschmutzungsabbau wird die Idee sich abschwächender steigender Skalenerträge eingeführt. Dieses Vorgehen stellt nicht nur eine Lösung des theoretischen Problems der negativen Verschmutzung dar, sondern bewährt sich auch hinsichtlich der empirischen Plausibilität der Vermeidungstechnologie.

RÉSUMÉ

Les modèles de la courbe environnementale de Kuznets, en particulier ceux avec une technologie explicite de réduction de pollution, impliquent souvent que la pollution devienne négative à long terme. C'est évidemment une prédiction peu probable. La présente contribution examine tout d'abord le problème de la pollution négative, en traitant deux approches qui sont adoptées dans des modèles EKC existants. Une nouvelle approche est ensuite proposée. L'idée des économies d'échelle s'affaiblissant est introduite, puisque l'hypothèse des économies d'échelles perpétuelles est sujette à caution. Cette procédure est, d'une part, une solution pour le problème théorique de la pollution négative, et, d'autre part, elle est empiriquement plus plausible.