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The Environmental Kuznets Curve

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Introduction

The presumption is often made that economic growth and trade liberalization are good for the environment. The risk being that policy reforms designed to promote growth and liberalization may be encouraged with little consideration of the environmental consequences (Arrow et al., 1995). At the early stages of the environmental movement some scientists began to question how natural resource availability could be compatible with sustained economic growth (Meadows, Meadows, Zahn, & Milling, 1972). Neoclassical economists, on the other hand, fiercely defended that limits to growth due to resource constraints were not a problem (e.g. Beckerman, 1974). Thus the debate between the so-called environmental pessimists and optimists began as centered on nonrenewable resource availability. Although the debate has continued throughout the years (e.g. Beckerman, 1992; Lomborg, 2001; Meadows, Meadows, & Randers, 1992; Meadows, Meadows, & Randers, 2004) the pessimists were perhaps naïve in extrapolating past trends without considering how technical progress and a change in relative prices can work to overcome apparent scarcity of limits (Neumayer, 2003b: 46).

In the 1980s large issues such as ozone layer depletion, global warming and biodiversity loss began to refocus the debate around the impacts of environmental degradation on economic growth. Interest was shifting away from natural resource availability towards the environment as a medium for assimilating wastes (i.e. from 'source' to 'sink') (Neumayer, 2003b: 47). Also, following the Brundtland Report (WCED, 1987), the discourse of sustainable development largely embraced the economic growth logic as a way out of poverty, social depravation and also environmental degradation particularly for the developing world. Thus the relationship between economic growth and the environment came under increased scrutiny.

In the 1990s the empirical literature on the link between economic growth and environmental pollution literally exploded (see Cole & Neumayer, 2005; Stern, 2003; 2004 for overviews). Much of this literature sought to test the Environmental Kuznets Curve (EKC) hypothesis, which posits that in the early stages of economic development environmental degradation will increase until a certain level of income is reached (known as the turning point) and then environmental improvement will occur. This relationship between per capita income and pollution is often shown as an inverted U-shaped curve. This curve is named after Kuznets (1955) who hypothesized that economic inequality increases over time and then after a threshold becomes more equal as per capita income increases. In the early 1990s the EKC was introduced and popularized with the publication of Grossman and Krueger's (1991) work on the potential environmental impacts of NAFTA, and the 1992 World Bank Report (Shafik & Bandyopadhyay, 1992; World Bank, 1992).

This chapter will critically review the theoretical and empirical literature on the EKC. We find that recent improvements in empirical methods address a number of past criticisms, which adds robustness to the EKC results for certain environmental pollutants. However economic growth and liberalization should not be thought of as a panacea for environmental problems particularly in the developing world. Recent work has demonstrated the unpleasant implications for many less developed countries

(LDCs) that are entering the stage of economic development where emission levels are set to rise rapidly (Cole et al., 2005).

The theoretical case

Why might economic growth benefit the environment? There are a number of theoretical explanations that suggest the sink side of the environment will be less impacted as incomes rise. First, environmental quality is often cited as a normal good, if not even a luxury good. In other words, the income elasticity of demand for environmental quality is greater than zero, possibly even greater than one, or as income grows environmental concern rises as well, perhaps even more than proportionally so (Beckerman, 1992; World Bank, 1992). In addition, rich countries may be better able to meet the higher demands for environmental protection through their institutional environmental capacity (Neumayer, 2003b: 77). However, it is contested whether rich people care more about the environment than the poor (e.g. Martinez-Alier, 1995), and the available evidence is far from conclusive (see Kriström & Riera, 1996). Second, it is likely that economic growth increases the possibility that more modern and less pollution intensive man-made capital and technology are introduced (Grossman & Krueger, 1995). While pollution per unit of output might go down, absolute pollution levels might very well go up as economic growth increases. Therefore the effect of technological change on pollution is in principle ambiguous (Lopez, 1992).

Third, as economic development progresses and income grows, the share of industry will go down as services goes up, thus sectoral changes may favor less-polluting sectors (e.g. Jänicke, Binder, & Mönch, 1997). Yet if starting from low income levels, structural changes in the economy will most likely have a detrimental effect on the environment. Pollution will increase as the share of agriculture goes down and industry goes up. Also there may be limitations in the scope of these changing patterns of output, given that people's revealed preferences indicate that pollution-intensive material goods are still highly valued (Neumayer, 2003b: 81). It is also suspected that high-income countries have become cleaner because they have exported their pollution-intensive industry to LDCs, also known as the "pollution haven hypothesis". By importing goods that are resource or pollution intensive developed countries' environmental track records appears cleaner than they actually are. Despite some recent evidence for such claims, the empirical record for this argument remains somewhat inconclusive (Neumayer, 2001).

Fourth, rising income brings population growth rates down, therefore population pressure on the environment decreases. Although not all agree population growth is detrimental to the environment (Simon, 1996), the evidence is clear: larger populations generate more emissions (UNDP, 1999). However with considerable variance in the data, it is clear that population growth is determined by factors other than a country's income level as well (Neumayer, 2003b: 82). Thus economic growth is neither a necessary nor a sufficient condition for reducing population growth. For example it is argued that investing in education for women and providing retirement insurance schemes are the best ways to reduce population growth (ibid).

Underpinning the above arguments is that economic growth is not logically equivalent to rising output in material terms but to rising output in value terms (Pezzey, 1992:

324). Thus economic value needs to be decoupled from resource depletion and environmental destruction. However from the theoretical discussion above no conclusive answer is found that explains how this decoupling will occur.

Examining the empirical evidence

As we have discussed, the theoretical explanations are mixed: economic growth may or may not benefit the environment. Therefore, we will now examine the empirical literature on the link between economic growth and the environment.

Unfortunately, results from empirical studies have also been mixed, both for different environmental indicators and also, perhaps more worryingly, for different studies looking at the same environmental indicator. But the results overall point toward three

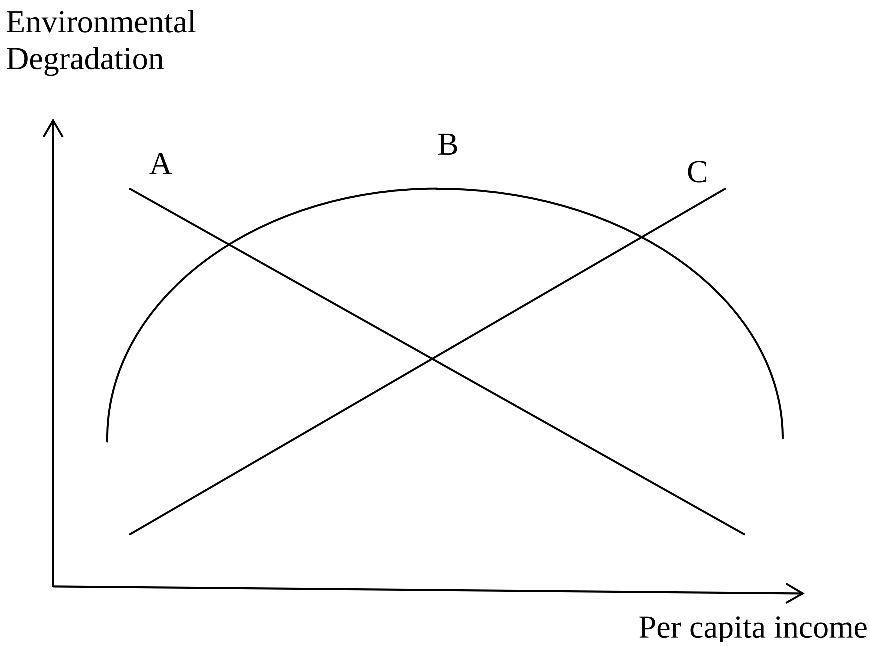

Figure 1 Environmental degradation and per capita income.

qualitative ideal-type cases to be distinguished (see Figure 1).

Formally, in the majority of studies, the basic EKC equation that is estimated is of the following form:

$$E_{it} = (\alpha + \beta_i F_i) + \delta Y_{it} + \phi(Y_{it})^2 + k_t + \varepsilon_{it} \qquad (1)$$

Where *E* denotes the environmental indicator, either in per capita form or in the form of concentrations, *Y* denotes per capita income, *F* denotes country-specific effects, *k* refers to year specific dummies or a linear time trend and *i* and *t* refer to country and year, respectively. In equation (1), if δ is negative and statistically significant but ϕ is statistically insignificant, then we get pattern A. These are indicators that show an unambiguous improvement with rising per capita income, such as access to clean water and adequate sanitation. If δ is positive and statistically significant but ϕ is statistically insignificant, then we get pattern C. These are indicators that show an unambiguous deterioration as incomes increase. These include per capita CO2 emissions. It is possible that these indicators will follow the EKC pattern but at much higher per capita income turning points that no countries have yet to reach (Neumayer, 2003b: 84). The pattern most often encountered is B, which follows if δ is positive and statistically significant and ϕ is negative and statistically significant. In this case, the estimated EKC has a maximum turning point per capita income level, calculated as $Y^* = (-\delta/2\phi)$. Table 1, taken from Cole and Neumayer (2005), provides the estimated turning points from a large number of EKC studies. Examples include suspended particulate matter, sulfur dioxide, carbon monoxide and nitrogen oxide emissions, fecal and total coliforms and the quality of ambient air (Neumayer, 2003b: 83-84).

There are a number of caveats to be kept in mind when looking at the results of empirical studies:

1. For some aspects of the environment, no turning point is in sight. Examples include CO2 emissions, already mentioned, direct material flows (but see Canas, Ferrao, & Conceicao, 2003 for contrary evidence; Seppala, Haukioja, & Kaivo-oja, 2001) and biodiversity loss (Asafu-Adjaye, 2003).
2. Econometric evidence captures historical/contemporary evidence. But it is not deterministic, i.e. future forecasts are highly problematic. We come back to this point later on, when we discuss the implications of the EKC literature for LDCs.
3. Even if an EKC relationship is found, there is the possibility of a second turning point. To check for this possibility, studies would need to add a cubic per capita GDP term to equation (1). Studies, which have found second turning points, include De Bruyn and Opschoor (1997) and Binder and Neumayer (2005).
4. Country-specific fixed and year-specific time effects are often required, but sometimes not included. Country fixed effects are required if per capita GDP or some other explanatory variables are correlated with country-specific time-invariant factors, such as geographical factors (climate, land size and resource endowments - see Neumayer, 2002a, 2004), or institutional quality. Year-specific time effects are required if there are global changes in environmental quality, perhaps due to global advances in technology, that have a roughly equal impact on countries at any given point of time.
5. Where country-specific fixed effects are included, the results are conditional on these effects and are contingent to the sample at hand. Strictly speaking, no out-of-sample predictions are possible for such estimation results.
6. If the environmental indicator and GDP p.c. are both trending over time (in technical terms: are non-stationary), then spurious regression results are possible. Year-specific time dummies mitigate, but do not solve the problem. Estimating the model in first differences might work as a solution. Co-integration is superior, but only if both variables are truly co-integrated. Very few studies have taken this potential problem seriously (Galeotti, Manera, & Lanza, 2006; Perman & Stern, 2003; Stern, 2000; Stern & Common, 2001; Wagner & Müller-Fürstenberger, 2005).
7. Where EKC exists, this could be partly due to a trade effect, i.e. rich countries may have partly become clean by importing products that are polluting in

production from lower-income countries. See Cole and Neumayer (2005) for some evidence.

8. Even where EKCs exist, with median GDP p.c. far below mean GDP p.c. the environmental implications can be unpleasant for many low-income countries for many years to come (Cole et al., 2005).

Why is there a distinction between these three different groups of environmental indicators? One possible explanation is that those that are very important to human health, such as local public goods, are not easily externalized and tend to improve already at low levels of income; whereas those that are global public goods, and are quite easy to externalize onto others, such as CO2 emissions, therefore worsen with economic growth (Shafik, 1994: 768). However one of the key questions that academics have addressed since the EKC hypothesis came under scrutiny is whether or not the EKC relationship is quasi-automatic or policy induced (Grossman et al., 1995).

EKC and policy

The reduced-form econometric models that have commonly been used in EKC studies do not test the pro-growth hypotheses as discussed above, or even investigate how changes in income influence environmental outcomes (Grossman et al., 1995: 372). However other studies have analyzed the factors that influence environmental change on a more disaggregate level (Neumayer, 2003b: 84). Selden, Forrest and Lockhart (1999) analyzed scale, composition and technique effects at the sector level to decompose changes in various US emissions.[1] Scale is indicated through the growth of emissions when the ratio of emissions to GDP remains constant. Composition effects are changes in emissions due to differential growth rates among sectors within an economy, and technique effects are all other changes in emissions per unit of output at the sectoral level, including energy efficiency, energy mix, and other technique effects.

They find that increased economic growth will trigger a composition shift of economic activity away from heavy manufacturing to services, and that economic growth may also generate environmental benefits through the development and adoption of new technology, i.e. cleaner production and improved energy efficiency. Therefore the policy prescription for alleviating at least some environmental problems may equal more economic growth, but their finding that emissions abatement technology played a significant role in bringing about improvement in environmental quality points towards a policy-induced response. They also find that global energy prices may signal emissions downturns because price incentives most likely provide incentives for increased energy efficiency. Therefore the question remains if emissions will rise again as international energy prices fall from their peaks or if policy is not introduced.

The empirical literature has also examined a range of factors that may influence environmental quality, such as democracy, literacy, income inequality and ENGOs. Using the panel data with which Grossman and Krueger (Grossman & Krueger, 1993;

[1] The emissions include particulates, SOx, NOx, non-methane volatile organic compounds, carbon monoxide and lead over the time period from 1970 to 1990.

Grossman et al., 1995) established the EKC, Torras and Boyce (1998) define higher political and civil liberties and increased literacy rate as constituting a more equitable power distribution. They find that a more equitable power distribution tends to result in better environmental quality and that literacy and rights appear to be strong predictors of pollution levels in low income countries. Therefore the policy implications may be to not put a brake on economic growth in LDCs, but to focus on interventions that may lead to a more equitable power distribution, such as increased literacy and rights.

Barrett and Graddy (2000) using the same data find that for air and water pollution, an increase in civil and political freedoms significantly improves environmental quality. They find, especially with SO_2, that a low freedom country with an income level near the peak of the EKC can reduce its pollution at least as much by increasing freedoms as it can by increasing income per capita. This has policy relevance, the authors argue, in that political freedoms should be treated independently from incomes. However, freedoms show up being significant for measures directly related to human health but not others, therefore perhaps something other than an induced policy response lies behind the EKC relationships for water quality measures (e.g. nitrates).

In contrast, Neumayer (2002b) shows that democracies exhibit stronger international environmental commitment than non-democracies, but he finds that there is weak evidence for a link between democracy and environmental outcomes. This raises questions about how we manage long term or global pollutants – democracies may not address these environmental quality issues; therefore perhaps other deliberative processes are needed. Also, we need to understand what it is about democracies that impact on environmental commitments – is it rule of law, specific types of institutions, etc? Binder and Neumayer (2005), using the same data as Torras and Boyce (1998), find that environmental non-government organization (ENGO) strength is associated with lower air pollution levels even after controlling for variation in income, democracy, business lobby strength, literacy and income inequality. Thus, they highlight that ENGOs are important drivers of policy-induced responses. Furthermore, Neumayer (2003a) finds that countries with left-wing governments improve environmental quality more than right-wing governments, whereas the effect of a corporatist governance of the economy is largely ambiguous. Cole (2007) reports that more corrupt countries have a worse environmental record than countries with less corruption. Thus there are a myriad of factors that may influence increased demand for environmental regulation as incomes rise.

EKC and Trade

As discussed, the EKC provides empirical evidence to test the trade, economic growth and environment hypothesis. The debate is typically divided between the so-called optimists and pessimists who believe that trade as a driver of economic growth is either good or bad for the environment (see e.g. Bhagwati, 1993; Daly, 1993). Studies have found that the EKC inverted-U relationship may be a result of the changing scale, composition and technique patterns that appear to accompany liberalized trade and economic growth (Grossman et al., 1993, 1995; Heil & Selden, 2001; Suri & Chapman, 1998). However these structural changes from heavy industry towards services in the now rich countries may be a result of the South’s specialization in the extraction of natural resources and the production of labor and pollution intensive goods (Stern, 1998). The fact that developed countries may now be importing their pollution-intensive output from the developing world may therefore explain the reductions in local air pollution experienced in most developed countries in recent years (Cole et al., 2005).

The pollution haven hypothesis, as previously mentioned, is one attempt to explain these changes in trade patterns. It claims that less stringent regulation in developing countries will provide them with a comparative advantage in the production of pollution-intensive goods over developed countries (Cole, 2004). Therefore the North will specialize in clean production whereas the South in pollution-intensive production. However the data is mixed. Some find no evidence suggesting that the stringency of a country's environmental regulation significantly impacts competitiveness of pollution-intensive firms (Jaffe, Peterson, Portney, & Stavins, 1995; Jänicke et al., 1997), whereas others have found some evidence of pollution haven pressures (Antweiler, Copeland, & Taylor, 2001; Birdsall & Wheeler, 1993; Cole & Elliott, 2003; Mani & Wheeler, 1998; Van Beers & Van den Bergh, 1997). Cole (2004) examined North-South trade flows for pollution intensive products, and found evidence of pollution haven effects, but did not find they were widespread. In fact, he found that pollution haven effects may be small compared to other EKC explanatory variables such as increased demand for environmental regulations, increased investment in abatement technologies, trade openness, structural change away from manufacturing, and increased imports of pollution intensive outputs (2004: 79).

Indeed, there is some evidence that trade openness may have beneficial effects on the environment. Neumayer (2002c) reports evidence suggesting that countries more open to foreign trade have a higher likelihood to ratify multilateral environmental agreements. Perkins and Neumayer (2008) examine the claim that outward orientation helps countries to reduce their pollution intensity, that is the amount of pollution generated per unit of GDP. They find that countries, which import a larger share of their machinery and manufactured goods from countries with lower pollution intensity, manage to lower their CO_2 and SO_2 pollution intensity faster than others. However the question remains whether or not LDCs will be able to follow the pollution-income paths of developed countries (Cole, 2004).

EKC and LDCs

One of the key issues that the EKC has raised is whether the same pattern of growth versus environmental impact can be replicated by the now poor countries in the future. Is the policy ramification for poor countries that they should grow themselves out of environmental problems rather than implementing stricter regulation now? Recent research has engaged with these important questions.

Cole and Neumayer (2005) examine the implications of the EKC for pollution trends in LDCs. They first review the robustness of the EKC critique, suggesting that the EKC may be more robust than some studies have claimed. Then, they explore whether LDCs are likely to follow the compositional changes that developed countries have followed. They demonstrate evidence that the emissions reductions in now rich countries are in part due to export of pollution-intensive domestic production to LDCs, thus suggesting that current poor countries will not be able to replicate this experience. They then examine how long it will take different regions in the developing world to reach EKC turning points according to three economic growth projections and the most widely cited EKC studies. They demonstrate some unsettling conclusions that environmental quality is predicted to get worse for many years to come, even under high economic growth scenarios. Cole and Neumayer (2005) contribute to the literature by explicitly considering whether LDCs can expect to follow an EKC or when LDCs can expect to experience an improvement in environmental quality. Also, while some studies have predicted future global emission trajectories of certain air pollutants, no analysis had been undertaken at the regional level.

In Dasgupta, Laplante, Wang and Wheeler's (2002) critical review of the EKC they discuss four different viewpoints regarding the EKC relationship. First is the view that pollution rises to a horizontal line of maximum emissions as globalization forces a "race to the bottom" in environmental standards. Second, in a similar pessimistic outlook, some believe that environmental impacts will continue to increase as "new toxics", such as CO2 emissions and carcinogens, replace traditional pollutants that may have exhibited an inverted U-shape curve. Third is the conventional EKC, and fourth is the "revised EKC" where pollution begins falling at lower income levels. Dadgupta et al. remain optimistic (with caveats) that the EKC is lowering and flattening in LDCs through increased formal and informal regulation.

Therefore we cannot take for granted that LDCs will experience an increased demand for environmental regulations. We need to consider what mechanisms are needed to translate society's preferences into policy making. For example, if the technique effect is emphasized through policy, then LDCs may be able to tunnel through the EKC, as the technology is already there. However, many criticisms of the EKC suggest that estimated turning points may not be indicative or expected turning points for developing countries, given the vast majority of turning points has been estimated using only OECD data.

Furthermore, there are other reasons why moving up the first part of the EKC curve could lead to very unpleasant implications for LDCs. What if a poor country stalls right at the moment of demographic transition (Neumayer, 2003b: 87)? What if environmental thresholds or irreversible environmental degradation occurs? Neumayer (2003b: 88) cautions that there are no guarantees that the external and internal conditions of low income countries are now the same as those conditions of high income countries were at the time of their development.

Conclusions

This chapter has critically reviewed the theoretical and empirical literature on the EKC. Explanations for the inverted U-shaped relationship between income and environmental degradation are complex and perhaps context specific, but recent improvements in empirical methods address a number of past criticisms, which adds robustness to the EKC results for certain environmental pollutants. We have discussed studies that have tried to analyze the ways in which countries manage to reduce their pollution load, which can suggest alternative explanations of the income-pollution relationship through variables such as energy price shocks, democracy, literacy, income inequality and ENGOs. It can be inferred that increased demand for environmental regulation may not be a quasi-automatic response with economic growth. Structural shift away from manufacturing may also explain the EKC relationship. Here we note how studies have examined this trade-composition effect, the pollution haven hypothesis, and the impacts of trade openness on environmental quality.

Questions were raised with serious ramifications for LDCs. Should today's developing countries follow the "grow now, clean up later" logic that has characterized the development paths of today's rich countries? Given predictions that some LDCs will not reach EKC turning points for decades to come, it is even more imperative that economic growth and liberalization should not be thought of as a solution for environmental problems. Therefore it might not be optimal, particularly for LDCs, to follow an EKC pathway for a variety of reasons, including: the likelihood of high environmental damage costs; the high cost of raising environmental quality after the damage has occurred; the potential of reaching environmental thresholds and causing irreversible environmental damage; and the potential damage to human health and economic productivity. A precautionary approach suggests that in order to decouple economic value from environmental degradation policy responses are needed from the earliest stages of economic development. Thus, alternative socio-economic factors that would induce increased demand for environmental regulations should be given incentives along with measures to spur economic growth.

Table 1. Estimated turning points for various pollutants and studies.

• **Arsenic (concentration):**	Grossman and Krueger (1995): 4900$
• **Biological oxygen demand:**	Grossman and Krueger (1995): 7623$
• **Chemical oxygen demand:**	Grossman and Krueger (1995): 7853$
• **CO (emissions):**	Selden and Song (1994): 6241$ Cole et al. (1997): 9900$
• **Dissolved oxygen:**	Grossman and Krueger (1995): 2703$
• **Fecal coliform:**	Grossman and Krueger (1995): 7955$
• **Lead (concentration):**	Grossman and Krueger (1995): 1887$
• **Mercury (concentration):**	Grossman and Krueger (1995): 5047$
• **Nickel (concentration):**	Grossman and Krueger (1995): 4113$
• **Nitrates (concentration):**	Grossman and Krueger (1995): 10524$ Cole et al. (1997): 25000$
• **NOx (emissions):**	Selden and Song (1994): 12041$ Cole (2003): 14810$
• **SPM (ambient concentration):**	Shafik (1994): 3280$ Grossman and Krueger (1995): 6151$
• **SPM (emissions):**	Selden and Song (1994): 9811$ Cole et al. (1997): 7300$
• **SO2 (ambient concentration):**	Shafik (1994): 3670$ Grossman and Krueger (1995): 4053$
• **SO2 (emissions):**	Selden and Song (1994): 8916$ Cole (2003): 8691$ Stern and Common (2001): 18039$ (non-OECD only)
• **Total coliform:**	Grossman and Krueger (1995): 3043$

Note: Table taken from Cole and Neumayer (2005: 310)

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