19 Environmental policy and the environmental Kuznets curve: can developing countries escape the detrimental consequences of economic growth?

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Many have taken the policy implication of the so-called 'environmental Kuznets curve' (EKC) to be that poor countries can and perhaps should grow themselves out of environmental problems over time rather than tackling them with stricter regulation now. Many critics have argued, however, that the EKC suffers from severe methodological problems that cast doubt on the reliability of EKC results. In the face of such criticism, the aim of this chapter is to examine the implications of the EKC for pollution trends in less developed countries (LDCs). First, we consider the robustness of the EKC critique. Our review suggests that the EKC may be more robust than some studies have claimed. We then focus on one potentially more problematic criticism: the issue of whether compositional changes in developed countries (DCs) are responsible for emissions reductions and whether they at least partly result from the substitution of imports for pollution-intensive domestic production. If so, it is obviously doubtful whether today's LDCs can also expect to experience such compositional changes. Our results do suggest that the compositional reductions in pollution experienced by DCs stem, at least in part, from DC demand for pollution intensive output being increasingly satisfied by imports.[1] In other words, the now rich countries have become clean at least partly by exporting the dirty production of products to other, poorer countries. This implies that the current poor countries will not be able to replicate fully this experience.

The second part of the chapter therefore proceeds under the assumption that EKCs provide 'best case' scenarios. We take a number of the most widely cited EKC studies and consider their implications for pollution trends in developing countries. More specifically, taking the turning points estimated by these studies as given, we estimate how long it will take different regions in the developing world to reach these turning points using three economic growth scenarios.[2] Our results provide some unpleasant implications for many developing regions, particularly given that many of the criticisms of EKCs suggest that the estimated turning points are too low. Many aspects

of environmental quality are predicted to deteriorate for many years to come, even under our high economic growth scenario.

The implications of the EKC for developing countries have been widely neglected within the EKC literature. Studies have not explicitly considered whether LDCs can expect to follow an EKC or when LDCs can expect to experience an improvement in environmental quality. While some studies have predicted future global emission trajectories of some air pollutants (Selden and Song, 1994; Holtz-Eakin and Selden, 1995; Schmalensee *et al*., 1998), no analysis has been undertaken at the regional level. Furthermore none has considered such a range of pollutants or employed different growth scenarios. Given the enormous appeal that the results of the EKC literature have for policy makers in the developing world ('pollute first, clean up later'), we believe that the issues considered in this chapter are of great importance to the academic and policy debate on the growth–environment relationship. In addition we also discuss how environmental policy can help prevent becoming true some of the dire predictions following from the EKC results.

The remainder of the chapter is structured as follows. The first section outlines the basic EKC methodology and addresses some of the key criticisms that have been levelled at the EKC. The second section examines the composition effect experienced by DCs and asks whether this is a result of DCs effectively 'exporting' pollution. The third section provides our forecasts of pollution levels in LDCs and the fourth section concludes the chapter and considers the policy implications of our findings.

1 The EKC methodology and its critique

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

$$E_{it} = (\alpha + \beta_i F_i) + \delta Y_{it} + \phi (Y_{it})^2 + k_t + \varepsilon_{it} \tag{19.1}$$

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. Note that some studies include an income cubed term to allow for the possibility of an upturn in pollution at high per capita income levels. In equation (19.1), if $\delta > 1$ and $\phi < 1$ then the estimated curve has a maximum turning point per capita income level, calculated as $Y^* = (-\delta/2\phi)$.[3]

However this simple methodology has been the subject of growing criticism in recent years (see, for example, Arrow *et al*., 1995; Stern *et al*., 1996; Ekins, 1997; Perman and Stern, 1999; Stern and Common, 2001). The following are perhaps the most significant of these criticisms:

Econometric issues

Stern and Common (2001) and Perman and Stern (1999) criticize the EKC on two grounds. First, they claim that studies that use only OECD data will tend to estimate turning points at lower per capita income levels than those using data for the world as a whole. This arises because the developing countries are typically experiencing increasing emissions of even local air pollutants. The implication of this criticism is that the many studies to have estimated EKCs using only OECD data will have provided overly optimistic turning points. Second, they argue that per capita income and emissions are likely to be nonstationary variables. As a result, standard estimation is likely to generate spurious results. Cole (2003) examines the robustness of the EKC, paying particular attention to these two criticisms. This study firstly estimates a variety of functional forms for each of four different pollutants.[4] Across all of these models, little distinction is found between results estimated using only OECD data and those estimated using a larger sample containing both developed and developing countries. With regard to the second criticism, nonstationarity is found to be present for two of the four pollutants (for which a larger time series is available) and estimation is therefore undertaken in first differences to remove country-specific stochastic trends. An inverted-U relationship between income and emissions is still found for these two pollutants, with turning points in line with previous studies. The role played by nonstationary variables and OECD dominated samples may therefore be specific to the previously unused sulphur dioxide emissions data set that Stern and Common (2001) and Perman and Stern (1999) utilize.

Consistency of results

Ekins (1997) suggests that the EKC literature is overly optimistic in suggesting the existence of a systematic inverted-U relationship between income and pollution. He argues that estimated turning points are highly dependent on the choice of functional form (for example logs or levels) and the choice of data set and estimation method. In a similar vein, Harbaugh *et al*. (2000) find their EKC results to be highly sensitive to additional covariates and to changes in the nations, cities and years sampled. They are even unable to replicate Grossman and Krueger's (1995) results using the same covariates and the same sample, but using a revised version of the pollution concentrations data set that had been corrected for errors.[5] These studies would suggest that the reliability of the EKC is questionable, although it should be noted that Harbaugh *et al*. (2000) do appear to accept the existence of an inverted-U relationship between income and pollution and offer reasons why their results may not be capturing it. One reason offered is the fact that they are regressing *city-level* pollution concentrations against *national* explanatory variables de-

spite the fact that pollution around a given monitoring station is almost certainly related to local economic activity and local population density, neither of which they measure. In general, pollution concentrations data are very noisy and would ideally require the use of numerous dummy variables to control for site-specific pollution determinants, such as temperature, rainfall and so on. Such data are typically not available, however, perhaps suggesting why EKCs estimated using concentrations data appear somewhat fragile.

The results of Cole (2003) would certainly indicate that EKCs estimated using national per capita emissions are more robust. This study finds the inverted U-relationship between income and emissions to be robust across the variety of functional forms estimated (fixed or random effects, levels or first differences). In all estimations, a statistically significant inverted-U relationship is found between income and emissions, with turning points that are insensitive to the chosen functional form. Furthermore the inclusion of additional covariates (trade variables, political economy variables) does very little to affect this relationship. Finally, as already mentioned, the results were not sensitive to the use of a full or an OECD-only data set.

The role of trade

A number of studies have suggested that the EKC inverted-U relationship may be a result of the changing trade patterns that appear to accompany economic development (Grossman and Krueger, 1995; Suri and Chapman, 1998; Heil and Selden, 2001). As a country develops, the emphasis of the economy shifts from heavy industry towards services. This suggests that the developed world may now be importing its pollution-intensive output from the developing world, rather than producing it for itself. This fact may therefore explain the reductions in local air pollution experienced in most developed countries in recent years.

While we believe the first two criticisms are less problematic than has been claimed, there remains the possibility that EKC results are overly optimistic. The third criticism implies that a factor responsible for reducing emissions in DCs (the composition effect, as defined below) may be absent from LDCs' attempts to reduce emissions. This would obviously suggest that LDCs would have to rely increasingly on other ways of reducing emissions, for example through the use of environmental regulations. Since this argument casts doubt on whether today's developing countries will be able to experience the same pollution–income path as today's developed countries, we now examine it in more depth.

2 Are developed countries substituting imports for domestic pollution-intensive production?

The EKC relationship has typically been explained in terms of the interaction of scale, composition and technique effects. *Ceteris paribus*, scale effects are likely to prove environmentally damaging and arise as a result of the increased scale of economic activity associated with economic growth. Composition effects refer to the fact that, as a country develops, its economy sees a changing emphasis from agriculture to pollution-intensive, heavy industry and then towards light manufacturing and services. In isolation, the composition effect for a developed economy is likely to reduce pollution, but can lead to increases in pollution for developing countries at the early stages of industrialization. Finally the technique effect refers to changing techniques of production that may accompany economic growth, often because of increased demand for environmental regulations. Again, in isolation, this effect is likely to reduce pollution. The EKC is therefore often explained in terms of the dominance of scale effects over composition and technique effects at early stages of development, with later stages of development associated with the dominance of composition and technique effects over scale effects.

But will today's LDCs be able to experience environmentally beneficial composition and technique effects? *In principle*, there is no reason why LDCs will not be able to experience changing techniques of production as a result of increased environmental regulations together with greater access to new technology. However, if the composition effect is a result of an increasing share of pollution-intensive consumption being met by imports, it is questionable whether the developing world can benefit from such changes.

Numerous studies have suggested that the EKC may be a statistical artefact that results from the developed world exporting its pollution abroad (Grossman and Krueger, 1995; Suri and Chapman, 1998; Heil and Selden, 2001).[6] If true, this implies that the LDCs will not be able to follow the same pollution–income path as the DCs since they will have no-one to whom they can pass their pollution-intensive industries. But is this accurate? The aim of this section is firstly to examine to what extent compositional changes within DCs have reduced pollution emissions and, secondly, to consider whether these changes are a result of DC demand for pollution-intensive output now being met by production from LDCs.

Isolating the effect of compositional changes on pollution

Using sectoral production data and sectoral pollution intensities from Hettige *et al*. (1994), it is possible to identify the composition effect, holding constant the scale and technique effects.

The first step is to calculate each sector's share of total production in 1970. If these percentage shares are then applied to 1996 sectoral production data,

we have effectively applied 1970s composition to 1996 production (for example, if ISIC sector 351 formed 10 per cent of total 1970 production, we scale the production of sector 351 in 1996 so that it forms 10 per cent of total 1996 production, and do the same for each sector). We then multiply 1996 sectoral production and 1996 counterfactual sectoral production (estimated using the composition of production in 1970) by the same set of sectoral pollution intensities and aggregate across sectors. The difference between the two 1996 aggregates tells us how much higher manufacturing emissions would have been in 1996 if the composition of production was the same as that in 1970. Table 19.1 expresses this quantity as a percentage of counterfactual 1996 emissions (that is, emissions calculated using 1970s composition of production), thereby indicating the percentage reduction in air pollution between 1970 and 1996 as a result of compositional changes alone. This is reported for four air pollutants and four developed countries.[7]

Table 19.1 The percentage change in air pollution from manufacturing as a result of compositional changes alone, 1970–96

	NO_2	SO_2	CO	SPM
USA	–4.9	–12.5	–12.0	–11.2
Canada	–3.2	–18.1	–10.8	–12.6
Japan	–31.7	–31.9	–36.1	–30.6
UK	–5.8	–18.1	–14.0	–11.3

Table 19.1 indicates, for example, that US SO_2 emissions from manufacturing in 1996 were 12.5 per cent lower than if the composition of production in 1996 was the same as that in 1970; that is, *the composition effect alone* has reduced manufacturing SO_2 emissions by 12.5 per cent, relative to 1970. Since we are comparing 1996 production and pollution data with 1996 data assuming 1970s composition, we are clearly removing any scale effect. The total scale of manufacturing production is the same in both cases. Similarly, since we are applying the same sectoral pollution intensities in each case, emissions are unaffected by any technique effect.

Table 19.1 suggests that composition changes have reduced air pollution emissions, particularly SO_2, CO (carbon monoxide) and SPM (suspended particulate matter), by a significant amount over the period of consideration. Japan appears to have experienced the greatest composition effects. To ascertain whether LDCs can experience similar compositional emissions reductions we need to know whether these reductions derive from DCs substituting pollution-intensive imports from LDCs for their own pollution-intensive production.

A number of studies have attempted to assess the extent to which changing trade patterns can explain the composition effect. Suri and Chapman (1998) include the ratio of manufactured imports to domestic manufacturing production, and the same ratio for exports, as determinants of energy use. They generally find that the import ratio has a negative relationship with energy use while the export ratio has a positive relationship, and therefore suggest that domestic production is being replaced by imports. Similarly Heil and Selden (2001: 46) find that increased trade intensity is associated with decreased carbon emissions in high-income countries and increased emissions in low- and middle-income countries. They suggest that 'the greater trade intensities of high-income countries may have helped those countries expand their economies without proportional increases in carbon emissions, perhaps in part by 'exporting' their carbon emissions to lower income countries' (ibid.: 47). In a similar vein, Rock (1996) finds that those LDCs with outward-oriented trade policies have higher pollution intensities of GDP than those following inward-oriented policies. Finally both Antweiler *et al.* (2001) and Cole and Elliott (2003) find some evidence to suggest that relatively low levels of environmental regulations can be a source of comparative advantage.

In contrast, Jänicke *et al.* (1997) find that the OECD countries generally remain net exporters of many pollution-intensive products, with little evidence of net exports as a share of consumption falling. It should be pointed out, however, that this finding does not necessarily imply that the demand for pollution-intensive products in high-income countries is *not* increasingly being met via imports. It is possible for the share of imports in domestic consumption to rise even though net exports as a share of consumption are not falling.[8] As a result, we believe the most direct way to investigate this issue is simply to estimate the share of imports in consumption, for each dirty industry, over the period 1970–96, which is what we do now.

The share of imports in consumption and output

It is widely recognized that the most pollution intensive industries are ISIC 34 Paper and Paper Products, ISIC 35 Chemical Products, ISIC 36 Non-Metallic Mineral Products and ISIC 37 Basic Metals.[9] For each of these industries, we calculate domestic consumption and divide this by the imports from developing countries within that industry.[10] Figures 19.1 to 19.4 provide our results for the USA, Canada, Japan and the UK, respectively.

These four figures provide strong evidence to suggest that the share of developing country imports in pollution-intensive consumption has increased over the period 1978–96 (1976–96 for Japan). Thus it would appear that developed country demand for pollution-intensive output is increasingly being satisfied by imports from abroad, in line with the findings of Suri and Chapman (1998) and Heil and Selden (2001).[11]

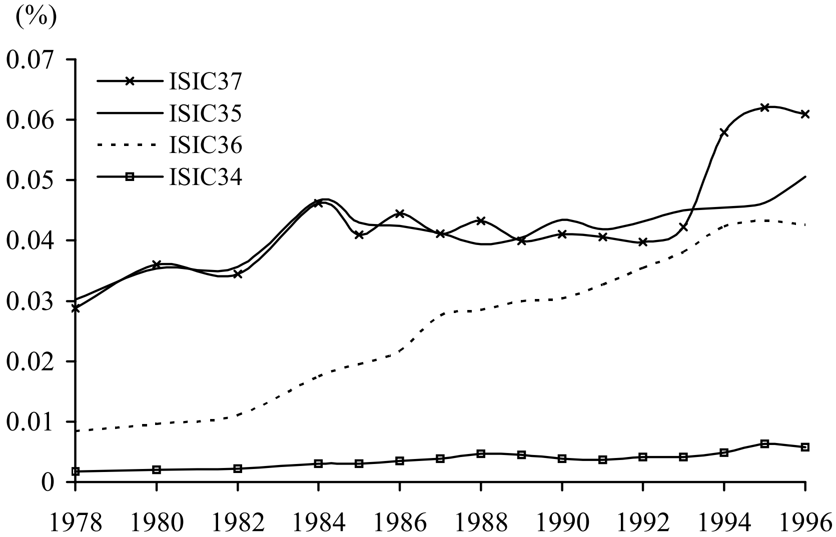

Figure 19.1 *The share of developing country imports in domestic consumption: USA, 1978–96, by pollution-intensive sector*

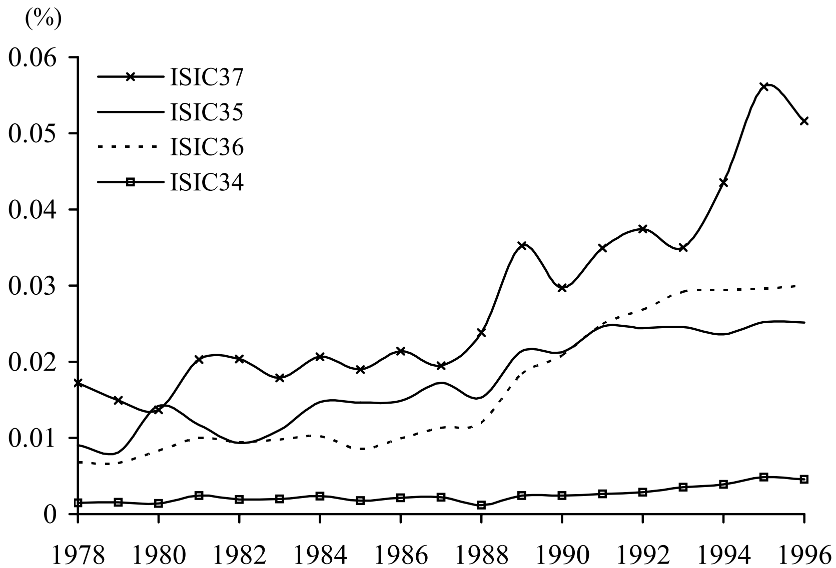

Figure 19.2 *The share of developing country imports in domestic consumption: Canada, 1978–96, by pollution-intensive sector*

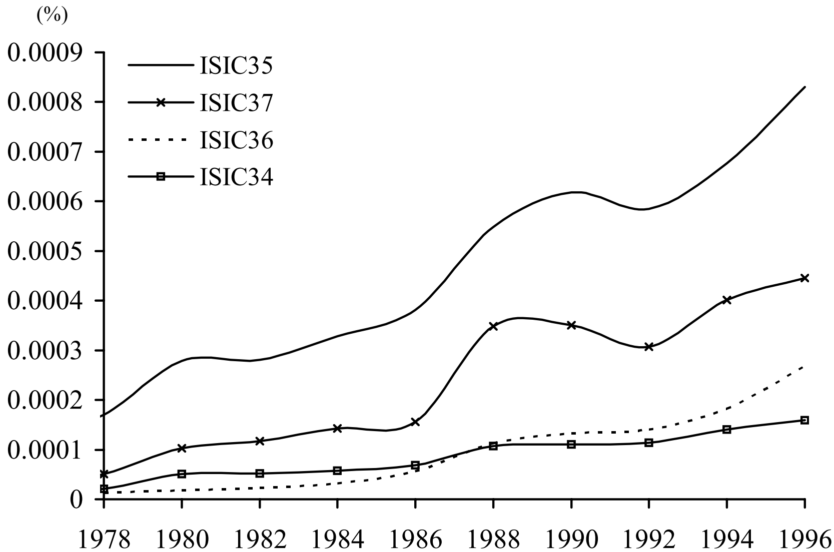

Figure 19.3 The share of developing country imports in domestic consumption: Japan, 1976–96, by pollution-intensive sector

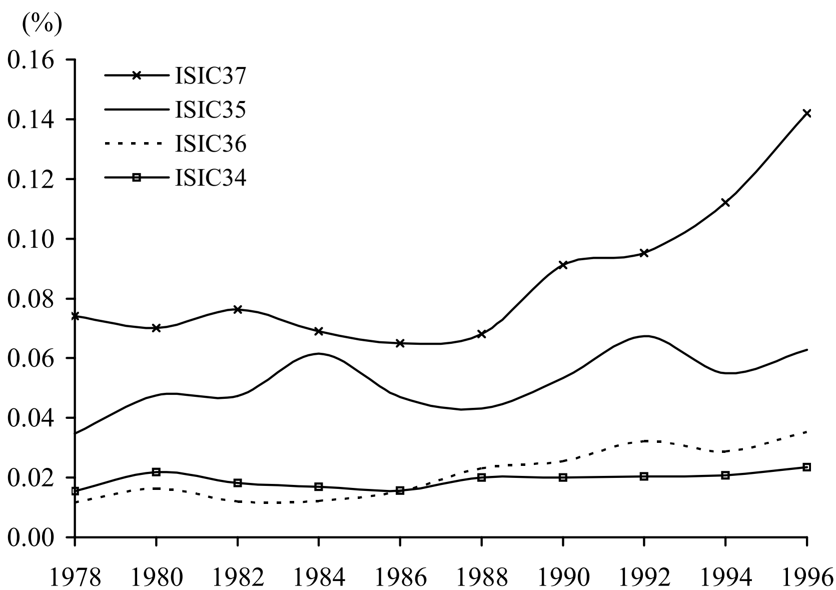

Figure 19.4 The share of developing country imports in domestic consumption: UK, 1978–96, by pollution-intensive sector

These findings raise doubts as to whether today's LDCs can experience compositional reductions in pollution comparable with those presented in Table 19.1. Emissions reductions in DCs have been attained through both compositional changes and increasingly stringent environmental regulations (the technique effect). If some of the emissions reductions due to the composition effect cannot be replicated by LDCs, it follows that the technique effect in LDCs must be stronger than was the case in DCs to bring about the same emissions reductions. Indeed, if the technique effect were unable to compensate for a possible reduced composition effect, it would appear likely that LDC emissions will peak at a higher level of per capita income than DC emissions. The turning points in the EKC literature may therefore be overly optimistic from the point of view of LDCs.

3 Forecasting pollution trends in LDCs

Our analysis therefore suggests that EKC results should be interpreted as 'best case scenarios'. The aim of this section is to show that, even if we accept these best case scenarios, and ignore the question marks that surround the EKC, we still find significant cause for concern. More specifically, we ask the following question. If LDCs will follow the same pollution–income path as DCs, and EKC studies have reliably estimated this path, when can we expect pollution levels to decline?

Forecasting methodology

All EKC studies considered here (and indeed practically all studies on the subject) employ gross domestic product (GDP) per capita in purchasing power parity in real US$1985 from the Penn World Tables (PWT) (Summers and Heston, 1991). Unfortunately, this data set does not contain all the countries in the world and currently extends to the late 1980s or early 1990s only, depending on the country. We take all countries in the data set for which GDP per capita figures were reported for 1988 or later. Countries were grouped into regions according to the classification contained in appendix A. Note that this classification follows EIA (2001), our source for regional growth projections. Regional GDP per capita is estimated as the population weighted average of all countries in a certain region for which the PWT provide estimates. Historical per capita growth rates taken from EIA (2001) are used to forecast these regional GDP per capita data to 1999.

Forecasts of economic growth over a long period of time are notoriously difficult. Few even try to forecast growth rates on a regionally disaggregated basis beyond a few years. Because of the close links between economic growth and energy consumption growth, the Energy Information Administration (EIA) has traditionally been interested in forecasting economic growth beyond the short term. EIA (2001) provides forecasts of economic growth

for our regions up to the year 2020, with different estimates according to a low reference and high growth scenario.[12] For the sake of argument we have extended these forecasts up to 2100 using the growth rates for 2015 to 2020 predicted by the EIA. Beyond the year 2100, we do not venture any forecasts.

Our forecasts beyond 2020 are mainly for the sake of argument and we fully acknowledge the enormous uncertainties involved in predicting income levels over such a long time period. We also note that the high growth scenario is bound to be impossible to sustain for certain regions as it would imply absurdly high income levels in the latter part of the 20th century. Having said this, the fact that we employ three different growth scenarios makes us confident that the growth rate actually realized in the not too distant future has a high probability of being close to one of the three different scenarios. Of course, given past experience, there is reason to expect that different regions will follow different scenarios, but we do not predict which scenario is most likely for each region.

Forecasting results

Table 19.2 provides an overview of predicted per capita GDP for the developing country regions to 2100, contingent on the scenario employed. Note that all GDP data are in real US$1985. To provide a better understanding of the differences between the three scenarios, the last column in Table 19.2 also lists the average annual growth rate between 2001 and 2030.

Table 19.3 lists the pollutants of interest, together with the source of the study and the estimated turning point. Shafik (1994), Selden and Song (1994), Grossman and Krueger (1995) and Cole *et al*. (1997) are four of the most widely cited studies.[13] The estimates by Cole (2003) and Stern and Common (2001) use data sets containing a reasonable number of developing countries and address the issue of nonstationarity. The potential importance of these features is discussed in the previous section and suggests that the estimated turning points from these studies are arguably more reliable than those from other studies. Information from Tables 19.2 and 19.3 is combined in Tables 19.4 and 19.5, which estimate the time period in which, or after which, the relevant turning point is estimated to be reached, depending on the pollutant considered and the growth scenario employed.

Looking at the results in Tables 19.4 and 19.5, one might distinguish between three groups of regions. The first group consists of Africa and India. It is clear that Africa is the region for which the EKC studies provide least hope for the future. For virtually all pollutants and all growth scenarios, pollution is predicted to rise for the most part of this century and frequently beyond the year 2100. Similarly bleak is the situation for India, for which only a few pollutants are estimated to improve before the year 2030. Even

Table 19.2 *Predicted income levels in developing country regions*

		2001	2010	2020	2030	2050	2075	2100	g (2001–30)
Africa	Low	1 216	1 293	1 319	1 341	1 387	1 446	1 508	0.34
	Ref.	1 253	1 520	1 800	2 125	2 962	4 486	6 793	1.82
	High	1 290	1 784	2 446	3 337	6 210	13 500	29 348	3.28
Central & South America	Low	4 266	4 945	5 777	6 762	9 263	13 727	20 342	1.59
	Ref.	4 394	5 811	7 860	10 658	19 598	41 960	89 841	3.06
	High	4 522	6 809	10 645	16 669	40 870	125 393	384 720	4.50
China	Low	2 925	4 053	5 372	7 078	12 290	24 493	48 814	3.05
	Ref.	3 097	5 546	9 799	17 211	53 098	217 103	887 676	5.91
	High	3 185	6 469	13 151	26 591	108 718	632 051	3 674 542	7.32
Other developing Asia	Low	2 821	3 479	4 256	5 142	7 506	12 046	19 331	2.07
	Ref.	2 904	4 081	5 779	8 084	15 823	36 631	84 800	3.53
	High	2 989	4 779	7 812	12 615	32 895	108 998	361 166	4.97
Eastern Europe & FSU	Low	4 021	5 060	6 815	8 727	14 310	26 554	49 272	2.67
	Ref.	4 140	5 936	9 240	13 685	30 019	80 137	213 929	4.12
	High	4 381	8 113	16 758	32 975	127 675	693 446	3 766 330	6.96
India	Low	1 824	2 376	3 192	4 270	7 642	15 817	32 739	2.93
	Ref.	1 877	2 786	4 324	6 685	15 977	47 475	141 075	4.38
	High	1 931	3 259	5 833	10 401	33 065	140 365	595 861	5.81
Middle East	Low	4 673	5 109	6 059	7 307	10 625	16 968	27 097	1.51
	Ref.	4 814	6 015	8 251	11 511	22 404	51 506	118 412	3.01
	High	4 956	7 057	11 186	18 017	46 744	153 916	506 806	4.45
South Korea	Low	10 326	13 254	17 822	23 788	42 378	87 220	179 511	2.88
	Ref.	10 633	15 540	24 145	37 143	87 904	258 031	757 411	4.31
	High	10 944	18 203	32 588	57 892	182 703	768 520	3 232 705	5.74
Mexico	Low	6 767	8 324	11 087	14 876	26 781	55 847	116 458	2.72
	Ref.	6 900	9 259	13 593	20 061	43 695	115 623	305 954	3.68
	High	7 032	10 300	16 634	27 052	71 548	241 326	813 976	4.65

Note: g is average annual percentage growth rate between 2001 and 2030.

Table 19.3 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
Faecal 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
NO_x (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
SO_2 (ambient concentration)	Shafik (1994): \$3670 Grossman and Krueger (1995): \$4053
SO_2 (emissions)	Selden and Song (1994): \$8916 Cole (2003): \$8691 Stern and Common (2001): \$18039 (nonOECD only)
Total coliform	Grossman and Krueger (1995): \$3043

then, in most cases pollution is predicted to rise for another 15 or 20 years or so, even in the high economic growth case.

The second group consists of Central and South America, China, Eastern Europe and the Former Soviet Union (FSU) as well as the Middle East. While China's starting level of income per capita is somewhat lower, higher predicted growth rates soon raise it to a level comparable with the other regions in this group. Even though this group has higher initial income levels and partly higher predicted growth rates than Africa and India, often pollution is still forecast to deteriorate for many years to come. Even with the high-growth scenario, most pollutants are not estimated to reach their peak before the next decade, and it will be even later for the lower-growth scenarios.

The third group consists of two countries, Mexico and South Korea, who have made it into the Organization of Economic Cooperation and Develop-

ment (OECD). Their initial income levels are high enough to ensure that many pollutants are already falling or will start to decline within the present decade. Only emissions of a few pollutants are predicted to continue increasing beyond 2020.

If we consider the results from the perspective of individual pollutants rather than regions, one might distinguish between pollutants with an estimated turning point below or close to US$5000 and those with higher turning points. For the first group of pollutants, the situation is already improving or will soon start doing so, with the exception of India and, more drastically, Africa. For the second group of pollutants, however, it will take well into the next decade, if not beyond, before environmental quality improves in many developing regions.

4 Discussion and conclusions

It is important that our findings are not misinterpreted. We suggest that some of the weaknesses of the EKC methodology are less problematic than has been claimed (by, for example, Stern and Common, 2001; Ekins, 1997), so that the major results of the EKC literature still hold (Cole, 2003). However we find evidence to suggest that emission reductions from compositional changes in developed countries arise as a result of an increasing share of developing country imports in the consumption of pollution-intensive products. Question marks therefore still remain over the EKC. The estimated turning points may be overly optimistic and it may be questionable whether LDCs will be able to reduce emissions to the same extent as the DCs.

In the second part of this chapter we have therefore accepted that EKC results may be best case scenarios, but have nevertheless assessed their implications for developing countries. We find that, for many water and air pollutants, the situation is predicted to worsen for many years to come for most regions in the developing world (with the possible exception of Mexico and South Korea). This is true even if a high-growth scenario is employed which would yield the estimated turning point more rapidly. Taking the EKC results, which (to repeat) might be overly optimistic, at their face value therefore leads to some bleak conclusions for many developing country regions. These implications of the EKC results might not be so important if emissions in developing regions were growing from very low levels. However this is not the case, since existing emission levels are already high, with severe human health impacts (see, for example, World Bank, 1992: Mage *et al*., 1996; WRI, 1998). David Wheeler (2002: 4), from the World Bank's Development Research Group, suggests that air and water pollution kills and seriously affects so many people that 'numerous benefit–cost studies have indicated that air and water pollution control are competitive with other social investments, even in very poor countries that have pressing needs for basic education and health care'.

Table 19.4 Estimated time periods for water pollution to start declining

	Y*	Arsenic (conc.) G&K (1995) 4900	BOD G&K (1995) 7623	COD G&K (1995) 7853	Dissolved oxygen G&K (1995) 2703
Africa	Low	>2100	>2100	>2100	>2100
	Ref.	2080–85	>2100	>2100	2035–40
	High	2040–45	2055–60	2055–60	2020–25
Central & South America	Low	2005–10	2035–40	2035–40	↓
	Ref.	2001–05	2015–20	2015–20	↓
	High	2001–05	2010–15	2010–15	↓
China	Low	2015–20	2030–35	2030–35	↓
	Ref.	2005–10	2015–20	2015–20	↓
	High	2005–10	2010–15	2010–15	↓
Other developing Asia	Low	2025–30	2050–55	2050–55	↓
	Ref.	2015–20	2025–30	2025–30	↓
	High	2010–15	2015–20	2020–25	↓
Eastern Europe & FSU	Low	2005–10	2020–25	2025–30	↓
	Ref.	2005–10	2015–20	2015–20	↓
	High	2001–05	2005–10	2005–10	↓
India	Low	2035–40	2045–50	2050–55	2010–15
	Ref.	2020–25	2030–35	2030–35	2005–10
	High	2015–20	2020–25	2025–30	2005–10
Middle East	Low	2005–10	2030–35	2030–35	↓
	Ref.	2001–05	2015–20	2015–20	↓
	High	↓	2010–15	2010–15	↓
Mexico	Low	↓	2001–05	2005–10	↓
	Ref.	↓	2001–05	2001–05	↓
	High	↓	2001–05	2001–05	↓
South Korea	Low	↓	↓	↓	↓
	Ref.	↓	↓	↓	↓
	High	↓	↓	↓	↓

Note: BOD: biological oxygen demand; COD: chemical oxygen demand; G&K (1995):

Faecal coliform G&K (1995) 7955	Lead G&K (1995) 1887	Mercury G&K (1995) 5047	Nickel G&K (1995) 4113	Total coliform G&K (1995) 3043	Nitrates (Concentrations) G&K (1995) 10524	Nitrates (Concentrations) Cole *et al.* (1997) 25000
>2100	>2100	>2100	>2100	>2100	>2100	>2100
>2100	2020–25	2080–85	2065–70	2050–55	>2100	>2100
2055–60	2010–15	2040–45	2035–40	2025–30	2065–70	2090–95
2035–40	↓	2005–10	↓	↓	2060–65	>2100
2015–20	↓	2001–05	↓	↓	2030–35	2055–60
2010–15	↓	2001–05	↓	↓	2015–20	2035–40
2030–35	↓	2015–20	2005–10	2001–05	2045–50	2075–80
2015–20	↓	2005–10	2005–10	↓	2020–25	2035–40
2010–15	↓	2005–10	2001–05	↓	2015–20	2025–30
2050–55	↓	2025–30	2015–20	2001–05	2065–70	>2100
2025–30	↓	2015–20	2010–15	2001–05	2035–40	2060–65
2020–25	↓	2010–15	2005–10	2001–05	2025–30	2040–45
2025–30	↓	2005–10	↓	↓	2035–40	2070–75
2015–20	↓	2005–10	↓	↓	2020–25	2040–45
2005–10	↓	2001–05	↓	↓	2010–15	2025–30
2050–55	2001–05	2035–40	2025–30	2015–20	2060–65	2090–95
2030–35	2001–05	2020–25	2015–20	2010–15	2040–45	2060–65
2025–30	↓	2015–20	2010–15	2005–10	2030–35	2045–50
2030–35	↓	2005–10	↓	↓	2045–50	>2100
2015–20	↓	2001–05	↓	↓	2025–30	2055–55
2010–15	↓	↓	↓	↓	2015–20	2035–40
2005–10	↓	↓	↓	↓	2015–20	2045–50
2001–05	↓	↓	↓	↓	2010–15	2035–40
2001–05	↓	↓	↓	↓	2010–15	2025–30
↓	↓	↓	↓	↓	↓	2030–35
↓	↓	↓	↓	↓	↓	2020–25
↓	↓	↓	↓	↓	↓	2015–20

Grossman and Krueger 1995. ↓: estimated pollution levels already falling.

Table 19.5 Estimated time periods for air pollution to start declining

		CO (Emissions)		NO_x (Emissions)		SPM (Concentrations)	
		S&S (1994)	Cole *et al.* (1997)	S&S (1994)	Cole (2003)	Shafik (1994)	G&K (1995)
	Y*	6241	9900	12041	14810	3280	6151
Africa	Low	>2100	>2100	>2100	>2100	>2100	>2100
	Ref.	>2100	>2100	>2100	>2100	2055–60	>2100
	High	2090–95	>2100	>2100	>2100	2025–30	2090–95
Central & South America	Low	2020–25	2050–55	2065–70	2070–75	↓	2020–25
	Ref.	2010–15	2020–25	2030–35	2035–40	↓	2010–15
	High	2005–10	2015–20	2020–25	2025–30	↓	2005–10
China	Low	2020–25	2040–45	2045–50	2050–55	2001–05	2020–25
	Ref.	2010–15	2020–25	2020–25	2025–30	↓	2010–15
	High	2005–10	2015–20	2015–20	2020–25	↓	2005–10
Other developing Asia	Low	2040–45	2060–65	2070–75	2080–85	2001–05	2040–45
	Ref.	2020–25	2035–40	2040–45	2045–50	2001–05	2020–25
	High	2015–20	2020–25	2025–30	2030–35	2001–05	2015–20
Eastern Europe & FSU	Low	2015–20	2035–40	2040–45	2045–50	↓	2015–20
	Ref.	2010–15	2020–25	2025–30	2025–30	↓	2010–15
	High	2005–10	2010–15	2015–20	2015–20	↓	2005–10
India	Low	2040–45	2055–60	2065–70	2065–70	2015–20	2040–45
	Ref.	2025–30	2035–40	2040–45	2045–50	2010–15	2025–30
	High	2020–25	2025–30	2030–35	2030–35	2005–10	2020–25
Middle East	Low	2020–25	2045–50	2055–60	2060–65	↓	2020–25
	Ref.	2010–15	2025–30	2030–35	2030–35	↓	2010–15
	High	2005–10	2015–20	2020–25	2020–25	↓	2005–10
Mexico	Low	↓	2010–15	2020–25	2025–30	↓	↓
	Ref.	↓	2010–15	2015–20	2015–20	↓	↓
	High	↓	2005–10	2010–15	2015–20	↓	↓
South Korea	Low	↓	↓	2001–05	2010–15	↓	↓
	Ref.	↓	↓	2001–05	2005–10	↓	↓
	High	↓	↓	2001–05	2005–10	↓	↓

Note: CO: carbon monoxide; NO_x: nitrogen oxides; SPM: suspended particulate matter; SO_2: sulphur dioxide. S&S (1994): Selden and Song (1994); G&K (1995): Grossman and Krueger

SPM (Emissions)		SO_2 (Concentrations)		SO_2 SO_2 (Emissions)		
S&S (1994) 9811	Cole *et al.* (1997) 7300	Shafik (1994) 3670	G&K (1995) 4053	S&C (2001) 18039	S&S (1994) 8916	Cole (2003) 8691
>2100	>2100	>2100	>2100	>2100	>2100	>2100
>2100	>2100	2060–65	2065–70	>2100	>2100	>2100
>2100	2055–60	2030–35	2035–40	>2100	>2100	>2100
2050–55	2030–35	↓	↓	2090–95	2045–50	2045–50
2020–25	2015–20	↓	↓	2045–50	2020–25	2020–25
2015–20	2010–15	↓	↓	2030–35	2015–20	2015–20
2040–45	2030–35	2005–10	2005–10	2060–65	2035–40	2035–40
2020–25	2010–15	2001–05	2005–10	2030–35	2015–20	2015–20
2015–20	2010–15	2001–05	2001–05	2020–25	2010–15	2010–15
2060–65	2045–50	2010–15	2015–20	↓	2055–60	2055–60
2035–40	2025–30	2005–10	2010–15	↓	2030–35	2030–35
2020–25	2015–20	2001–05	2005–10	↓	2020–25	2020–25
2035–40	2020–25	↓	↓	2055–60	2030–35	2030–35
2020–25	2015–20	↓	↓	2035–40	2015–20	2015–20
2010–15	2005–10	↓	↓	2020–25	2010–15	2010–15
2055–60	2045–50	2020–25	2025–30	2075–80	2055–60	2055–60
2035–40	2030–35	2015–20	2015–20	2050–55	2035–40	2035–40
2025–30	2020–25	2010–15	2010–15	2035–40	2025–30	2025–30
2045–50	2030–35	↓	↓	2075–80	2040–45	2040–45
2025–30	2015–20	↓	↓	2040–45	2020–25	2020–25
2015–20	2010–15	↓	↓	2030–35	2015–20	2015–20
2010–15	2001–05	↓	↓	2040–45	2010–15	2010–15
2010–15	2001–05	↓	↓	2025–30	2005–10	2005–10
2005–10	2001–05	↓	↓	2020–25	2005–10	2005–10
↓	↓	↓	↓	2020–25	↓	↓
↓	↓	↓	↓	2010–15	↓	↓
↓	↓	2005–10	↓	↓	↓	↓

(1995); S&C (2001): Stern and Common (2001); Y*: estimated turning point. ↓: Estimated pollution levels already falling.

It is here that environmental policy making could (and in our view should) intervene. As pointed out by Munasinghe (1999), if remedial, anticipative environmental policies are employed, then there is a real chance for LDCs to 'tunnel through' the EKC. This emphasizes the role of the so-called technique effect, that is, the pollution reduction brought about by technical progress and environmental regulation. Most studies agree that this effect has played an important role in reducing pollution in developed countries. LDCs should also be able to benefit from this effect, as long as a mechanism exists through which preferences can be translated into policy. It could even be argued that LDCs should benefit more than DCs from the technique effect, since pollution abatement technology is now more advanced and is improving faster than it has in the past. Therefore, a combination of strong and sophisticated environmental policies, together with progress in pollution abatement technology, provide the opportunity for developing countries to escape the pattern of the EKC. Economic growth could therefore be achieved with less environmental degradation than has been the case in developed countries.

Although many authors have criticized the EKC literature and its often implicit policy implications, we suggest that these criticisms do not necessarily invalidate the EKC's major findings. Our critique of the EKC literature therefore has a different thrust. We show that the implications of taking the EKC results at face value are bleak for many developing countries, even under the high-growth scenario. We therefore hope to have shown that, even if the supposedly optimistic EKC relationship is accepted, an environmental policy that followed the 'pollute first, clean up later' ideology would have very unpleasant implications for LDCs.

Notes

1. Declining pollution emissions in DCs have also arisen as a result of changing techniques of production, often the outcome of increased environmental regulations. In principle, LDCs can also experience an increased demand for such regulations as their income levels increase, although this should not be taken for granted. A mechanism is needed through which society's preferences can be translated into policy making. Inequality of power within LDCs, or a general lack of democracy, could prevent such a mechanism from operating (Torras and Boyce, 1998).
2. We do not address developed country regions (North America, Western Europe and Developed Asia) since, for the pollutants looked at here and the estimated turning points, pollution is estimated to decrease in these regions already.
3. Table 19.3 provides the estimated turning points from a large number of EKC studies.
4. Three air pollutants are considered, nitrogen oxides, sulphur dioxide and carbon dioxide, together with a measure of water pollution, biological oxygen demand.
5. Harbaugh et al. (2000) were unable to include all of the control dummies that Grossman and Krueger used (for example, the type of monitoring device) since these were not reported in the revised data set. This may, at least in part, explain the different results.
6. For a comprehensive overview of the so-called 'pollution haven' debate more generally, see Neumayer (2001a, 2001b).
7. By applying US intensities to Canada, Japan and the UK, we are assuming that the

relative pollution intensity of US industries is the same as that for Canadian, Japanese and UK industries.

8. For example, imagine that an industry in a particular country in one time period has production (P) = 50, imports (M) = 10 and exports (X) = 20. Consumption (C) would therefore = 40. M as a share of C = 0.25 and net exports as a share of C = 0.25. In the next time period, imagine P = 45, M = 10 and X = 22. Now C = 33, M as a share of C = 0.3 and net exports as a share of C = 0.36. In this scenario, net exports as a share of consumption have actually risen despite the fact that an increasing proportion of consumption is being met by imports, which has allowed production, and hence pollution, to contract within the industry. Thus, for the purposes of this chapter, imports, rather than net exports, as a share of consumption is the appropriate variable to examine.
9. See, for example, Hettige *et al*. (1994).
10. Domestic consumption within a sector is calculated as production plus imports minus exports. All data have been converted to 1985 US dollars and are from the OECD STAN database (OECD, 1998), with developing country imports provided by the World Bank's bilateral trade database.
11. We find similar trends to those in Figures 19.1–19.4 for *total* imports as a share of consumption and for imports (total or LDC) as a share of domestic production.
12. We do not employ different scenarios for population growth. This is because scenarios for economic growth exhibit much more variability than scenarios for population growth. EIA (2001) employs the United Nations reference scenario for its underlying population growth projections. Using different scenarios or a different source for projections of population growth would change the forecasted per capita economic growth rates only slightly.
13. We do not consider the second turning point in the relatively few estimations in the EKC literature that have included an income cubed term. This is consistent with our interpretation of EKCs as best case scenarios.

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