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Analysis

Trade, the pollution haven hypothesis and the environmental Kuznets curve: examining the linkages

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Abstract

This paper examines the extent to which the EKC inverted U relationship can be explained by trade and specifically the migration or displacement of 'dirty' industries from the developed regions to the developing regions (the pollution haven hypothesis (PHH)). Using detailed data on North–South trade flows for pollution intensive products the evidence for the PHH is assessed. Emissions of 10 air and water pollutants are then estimated, controlling for trade openness, structural change and 'dirty' North–South trade flows. Evidence of pollution haven effects is found, although such effects do not appear to be widespread and appear to be relatively small compared to the roles played other explanatory variables.

JEL classification: O10; O13; F18; Q25
Keywords: Economic growth; Trade; Environmental degradation; Pollution haven hypothesis; Environmental kuznets curves

1. Introduction

The possible existence of an inverted U-shaped relationship between per capita income and pollution—commonly known as an environmental Kuznets curve (EKC)—has attracted a great deal of attention in recent years (e.g. Shafik, 1994; Selden and Song, 1994; Grossman and Krueger, 1995; Cole et al., 1997). Perhaps inevitably, a burgeoning strand of this literature has been critical in nature—alleging that the EKC relationship is fragile and hence requires very careful interpretation (Arrow et al., 1995; Stern et al., 1996; Ekins, 1997; Stern and Common, 2001).

One specific criticism leveled at the EKC is that, in its simplest form, it does not account for trade patterns which themselves may at least partially explain a reduction in pollution in high income economies, with the reverse occurring in low income economies. The so-called pollution haven hypothesis (PHH) could potentially generate such trade patterns. The PHH claims that differences in the stringency of environmental regulations between the North and the South will provide the latter with a comparative advantage in pollution intensive production.[1] The North may therefore increasingly specialize in 'clean' production and rely on the South for the provision of pollution intensive output. If the PHH holds, then the EKC

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[1] Throughout this paper the 'North' refers to developed countries whilst the 'South' refers to developing countries.

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may not imply a net reduction in pollution, but simply a transfer of pollution from North to South.

Although a number of papers have examined the PHH and generated mixed findings (Birdsall and Wheeler, 1993; Jaffe et al., 1995; Janicke et al., 1997; Mani and Wheeler, 1998), a clear indication of the extent to which the PHH may be responsible for the EKC has yet to be provided. That is the contribution of this paper. By using detailed data on North–South trade flows, this paper examines the evidence for the pollution haven hypothesis, assesses the extent to which trade patterns are influencing pollution emissions and ascertains whether these trade patterns could be determined by divergent environmental regulations between the North and the South. Finally the analysis provides additional evidence as to whether the EKC relationship holds for a very wide range of environmental indicators.

The remainder of the paper is structured in the following manner: Section 2 considers the linkages between trade and the environment and examines trends in pollution intensive net exports (relative to domestic consumption) for North–South trade pairs. Section 3 contains the econometric EKC analysis, whilst Section 4 concludes.

2. Trade and the EKC

The growing literature on the topic of trade and the environment has suggested a large number of potential interactions between trade liberalization and pollution (Anderson and Blackhurst, 1992; Esty, 1994; Chichilnisky, 1994; Copeland and Taylor, 1994; Cole, 2000). It has been claimed, for instance, that trade openness may, ceteris paribus, reduce pollution emissions as countries facing greater competitive pressure may become more efficient in resource use. Others have examined the actual implementation of trade liberalization through the GATT/WTO and assessed the extent to which countries can restrict imports of environmental damaging goods. However, a more systematic analysis of the relationship between trade and the environment is provided by Grossman and Krueger (1991) who break down the resultant impact into three independent effects. The scale effect is the likely increase in pollution resulting from the economic growth generated by increased market access. The technique effect refers to the changing techniques of production that are likely to accompany liberalized trade. These may arise as a result of income-induced demand for greater environmental regulations and greater access to environmentally beneficial production technologies. Finally, the composition effect refers to the changing composition of an economy that may occur following an episode of trade liberalization as countries increasingly specialize in activities in which they enjoy a comparative advantage. It is this composition effect that is of most relevance to the EKC and is the mechanism through which the PHH would affect pollution. However, precisely how the composition effect affects pollution depends on a country's sources of comparative advantage and specifically on whether it has a comparative advantage in pollution intensive production.

The nature of the trade-composition effect has been the focus of a number of recent papers (Cole and Elliott, in press; Antweiler et al., 2001; Suri and Chapman, 1998). As the industrial economies have developed there has been a change of emphasis from heavy industry towards light manufacturing and services. In contrast, the developing countries have increased their specialism in the heavy industrial sectors. Suri and Chapman (1998) attempt to capture these structural changes by including the ratio of manufactured exports to domestic manufacturing production, and the same ratio for imports, as independent variables in a standard EKC for energy use. They find that the export ratio tends to have a positive relationship with energy use whilst the import ratio has a negative relationship. Stern (1998) claims that these structural changes may reflect the South's specialization in the production of goods that are intensive in natural resources and labor, in line with the Hecksher–Ohlin theory. If this has led to a general shift of manufacturing activity from North to South, then he speculates that this may have at least partly contributed to the EKC inverted U relationship. If so, then the EKC does not indicate that growth provides a 'cure' for environmental problems as many have claimed (for example, Beckerman, 1992) but simply shows that as incomes increase, the developed economies export their manufacturing industries. In a finite world this then implies that today's developing countries will have no one to whom their manufacturing industries can be passed. They are therefore

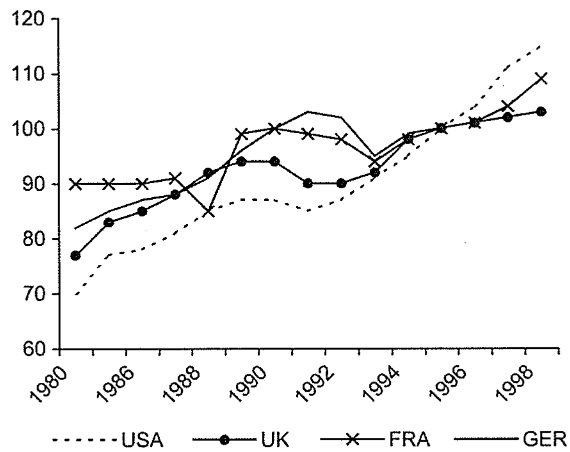

Fig. 1. Industrial production in a selection of developed economies, 1980–1998[2].

unlikely to be able to follow the same pollution-income path as today's developed economies.

Whilst this criticism of the EKC seems plausible, several clarifications are required. If global specialisation is occuring in line with factor abundance then the developed world should be increasing its specialisation in capital-intensive industries whilst the developing world should be specialising in labor-intensive sectors. However, capital intensive sectors are generally considered to be more pollution-intensive than labour intensive sectors (Cole and Elliott, in press; Antweiler et al., 2001). In a study of Japan, Mani and Wheeler (1998) claim that in relation to the five cleanest sectors, the five most pollution-intensive sectors were twice as capital intensive. In contrast the five cleanest sectors were approximately 40% more labour intensive. Thus, it is not obvious that specialisation in accordance with factor abundance could explain the shape of the EKC.

Furthermore, although the manufacturing share of GDP is falling steadily in developed countries, Fig. 1 indicates that industrial production is still increasing.

Thus, the contraction of manufacturing as a whole, relative to GDP, in the developed economies cannot alone explain declining emissions.[3] However, these changes can explain the falling pollution intensity of GDP and hence are likely to be one of several factors that have contributed towards falling pollution levels in the developed countries.

2.1. *The pollution haven hypothesis*

The pollution haven hypothesis states that differences in environmental regulations between developed and developing countries may be compounding this general shift away from manufacturing in the developed world and causing developing countries to specialize in the most pollution intensive manufacturing sectors. In the developed world the cost of meeting environmental regulations appears to be increasing regularly over time and in the USA alone was estimated to be $184 billion in 2000, equivalent to 2.6% of US GNP.[4] Since such costs are undoubtedly far lower in most developing countries it is possible that developing countries may possess a comparative advantage in pollution-intensive production. The PHH therefore provides further ammunition to those who claim that the EKC's inverted U-shape is simply caused by the developed countries exporting their pollution to the developing world.

Whilst it may appear intuitively plausible that environmental regulations will affect industrial competitiveness, evidence of low-regulation pollution havens is mixed. For example, Tobey (1990), Jaffe et al. (1995) and Janicke et al. (1997) find no evidence to suggest that the stringency of a country's environmental regulations influences trade in dirty products. In contrast, a study of import–export ratios for dirty industries by Mani and Wheeler (1998) found evidence of temporary pollution havens, while Lucas et al. (1992) and Birdsall and Wheeler (1993) found that the growth in pollution intensity in developing countries was highest in periods when OECD environmental regulations were strengthened. Antweiler et al. (2001) studied the impact of trade liberalization on city-level sulfur dioxide concentrations and found some evidence of pollution haven pressures, a result supported by a complementary study by Cole and Elliott (in press). Van Beers and Van den Bergh (1997)

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[2] Industrial production is manufacturing production together with mining, quarrying, electricity, gas and water.

[3] Cole (2000) also makes this finding.

[4] US Environmental Protection Agency 1990, estimated in 1992 $. According to Eurostat (New Cronos dataset), Environmental Protection Expenditure in Europe and the transition economies ranges from 0.73% of GDP to 2.5% (using data for latest year available, generally 1997,1998 and 1999).

also found evidence to suggest that regulations influence trade patterns, although Harris et al. (2002) claim that no such influence is found if fixed effects are included. In an extension of this literature Ederington and Minier (2003) and Levinson and Taylor (2002) specifically consider endogeneity issues, with the former arguing that environmental regulations should be treated as a secondary trade barrier, i.e. a means of protecting domestic industry. Both of these studies find that US environmental regulations, when treated as an endogenous variable, do influence US trade patterns.

Aside from endogeneity arguments, several other explanations have been offered as to why more widespread evidence of pollution havens has not been found despite the predictions of many theoretical studies (see e.g. Pethig, 1976; Chichilnisky, 1994; Copeland and Taylor, 1994). One such argument is that although environmental compliance costs appear large in absolute terms, as a proportion of a firm's total costs they are often less than 2% (see Walter, 1973,1982; Tobey, 1990; Dean, 1991). Hence the loss of competitiveness in the developed countries associated with the possession of more stringent regulations may be quite minimal. Other explanations of the limited evidence of the relocation of firms include the dependence of heavy industries on home markets; the fact that low regulation countries may have certain characteristics which deter inward investment such as corruption, poor infrastructure and uncertain or unreliable legislation; and the possibility that foreign investors may be concerned about their international reputation and do not wish to be perceived to be taking advantage of slack environmental regulations.[5] Finally, although the most pollution intensive sectors are experiencing a declining share of GDP, like manufacturing production in general (in Fig. 1), production levels are often not actually decreasing.

In order to examine specialization patterns for the most pollution-intensive industries a measure of a developed country's net exports with a developing country, as a proportion of the developed country's consumption from that sector, can be calculated. The role of consumption is vital when considering specialization patterns in the context of the PHH. Increasing net exports in dirty industries in developing countries may result from an increase in their share of consumption of dirty output, rather than from the relocation of such industries from the developed regions. Similarly, any falling net exports in dirty industries in the developed world may be due to a falling share of world consumption, rather than due to demand now being met by developing regions. Thus, net exports alone cannot indicate whether specialization is occurring in line with the PHH.

Net exports as a proportion of consumption (NETXC) are therefore calculated as follows for four trade-pairs and seven sectors for the period 1977–1995. The trade-pairs considered are USA–Asia, USA–Latin America, UK–Asia and Japan–Asia.[6] The sectors considered are the pollution intensive ISIC sectors 34–37 and the cleanest ISIC sectors 32, 38 and 39.[7]

$$\mathrm{NETXC}_{ikt}^{j} = \frac{X_{ikt}^{j} - M_{ikt}^{j}}{C_{ikt}} \tag{1}$$

where,

$$C_{ikt} = P_{ikt} - X_{ikt}^{w} + M_{ikt}^{w} \tag{2}$$

and X, M and P represent exports, imports and production, respectively, in developed country i, developing country/region j, sector k and time period t. Superscript w denotes world.

Previous studies to have examined the evidence for the PHH often consider only pollution intensive sectors (e.g. Janicke et al., 1997), allowing no comparison with the behaviour of clean sectors. Furthermore, such studies have considered only aggregate trade flows in which PHH consistent behaviour between specific trading nations may

[5] See Neumayer (2001) for a review of these issues.

[6] Note that 'Asia' does not include Japan.

[7] There is a general consensus that amongst the most pollution intensive sectors are ISIC 34, manufacture of wood and wood products, ISIC 35, manufacture of chemicals and chemical products, ISIC 36, manufacture of non-metallic mineral products and ISIC 37, basic metal industries. According to Hettige et al. (1994), the three ISIC sectors with the lowest pollution intensities are ISIC 32, textile, wearing apparel and leather industries, ISIC 38, manufacture of fabricated metal products and ISIC 39, other manufacturing industries.

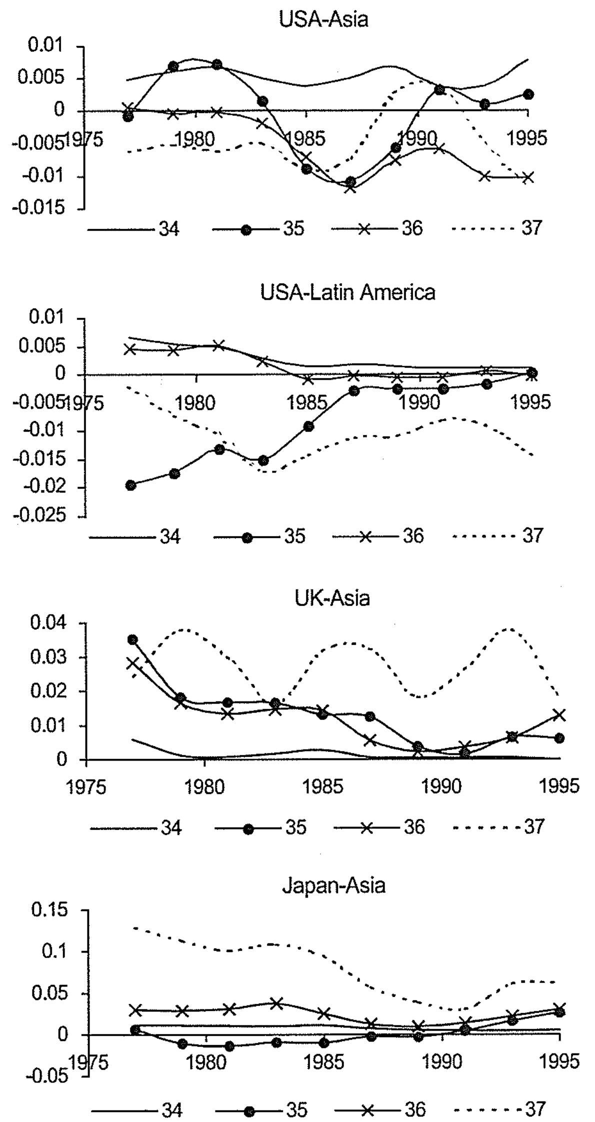

Fig. 2. Specialization patterns for pollution intensive industries, 1977–1995.

become extremely diluted. Fig. 2 provides NETXC for the four trade-pairs for the pollution intensive sectors. If NETXC is calculated as above for trade in pollution-intensive products for a developed country (with a developing region), then it should fall over time according to the PHH. This would indicate that the developed country was reducing its specialization in the industry relative to its consumption, implying that demand was now being met by the developing regions. Fig. 2 indicates that whilst there does not appear to be comprehensive support for the PHH, NETXC does behave in a PHH consistent manner throughout the period for certain sectors in certain trade-pairs. Furthermore, for some other sectors there are certain sub-periods in which NETXC fell. We may therefore be tempted to conclude that pollution havens have emerged between certain trading nations during certain periods.

However, Fig. 3 illustrates that many clean sectors have also experienced falling NETXC, particularly for

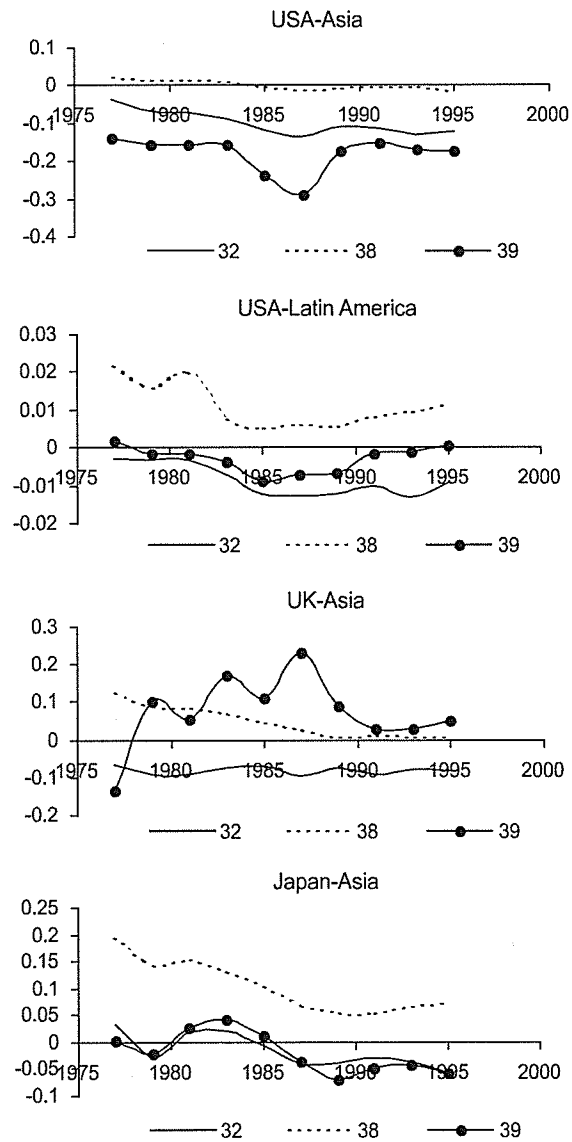

Fig. 3. Specialization patterns for clean industries, 1977–1995.

the USA–Asia and Japan–Asia trade-pairs. Since these sectors have very low pollution intensities this finding would obviously suggest that factors other than differences in environmental regulations must also be playing a role. Figs. 2 and 3 therefore indicate that whilst the developing nations are not reducing their specialization in all manufacturing sectors, the reductions that are occurring are not restricted to the most pollution intensive sectors.

3. Estimating EKCs

In the light of the above discussion, the following EKC model is estimated:

$$\ln E_{it} = \gamma + F_i + K_t + \delta ln Y_{it} + \phi(\ln Y_{it})^2 + \Psi(\ln Y_{it})^3 + \sigma \ln M_{it} + \lambda \ln \mathrm{DX}_{it} + \theta \ln DM_{it} + \eta \ln T_{it} + \epsilon_{it} \quad (3)$$

Where E is the pollutant, F is the country specific effects, K represents year specific effects, Y refers to per capita income, M represents the share of manufacturing in GNP, DX is the share of dirty exports to non-OECD countries in total exports and DM is the share of dirty imports from non-OECD countries in total imports and T is trade intensity. Subscripts i and t represent country and year, respectively.

Eq. (3) is estimated for a mixture of ten air and water pollutants for the period 1980–1997, for a sample of OECD countries. The air pollutants are carbon dioxide (CO_2), nitrogen oxides (NO_x), sulphur dioxide (SO_2), carbon monoxide (CO), suspended particulate matter (SPM) and volatile organic compounds (VOC). The water pollutants are levels of nitrates and phosphorous, together with two further indicators of water quality, biological oxygen demand (BOD) and levels of dissolved oxygen.[8] Appendix A contains further information on these pollutants together with information on all data used to estimate Eq. (3).

The share of manufacturing in GNP is included to indicate the extent to which structural change within the economy has affected pollution. Similarly, the share of pollution intensive exports and imports, from and to non-OECD countries, in total exports and imports will test for pollution haven effects.[9] The PHH would suggest that in the developed world the share of dirty exports in total exports has declined in recent years thereby causing a reduction in pollution emissions. Thus, we would expect to estimate a positive relationship between DX_{it} and E_{it}. In contrast, the PHH would imply that the share of dirty imports within total imports has increased in the developed countries as they now import their pollution intensive production from the developing world. Thus, if pollution haven effects are affecting pollution levels we would expect to estimate a negative relationship between DM_{it} and E_{it}. Trade openness, or trade intensity, is simply the ratio of the sum of imports and exports to GNP. As discussed in the previous section this may have either a negative or positive relationship with pollution emissions. Finally, the year specific effects are included to pick up any effects that are common to all countries but which change over time, an example being technological progress. Similarly, the country specific effects will pick up effects specific to each country which do not change over time, examples being climate and resource endowments.

Eq. (3) is estimated in a manner that overcomes many of the methodological criticisms that have been leveled at the EKC. First, the explanatory variables in Eq. (3) will indicate the role played

[8] In contrast to the other indicators of air and water quality, the higher the level of dissolved oxygen the *greater* the water quality.

[9] For each country DM is measured as the total value of imports from non-OECD countries in ISIC sectors 34 (wood Products), 35 (chemicals), 36 (non-metallic minerals) and 37 (metals), as a share of total imports. DX is measured in the same way for exports. The pollution intensity of each of these sectors is likely to vary from country to country depending on each country's production processes and regulations. Thus, if production of chemicals contracts by the same amount in two countries, and is replaced by imports from the South, the resultant impact on pollution may differ. Nevertheless, within each country it is almost certainly these five sectors that are the most pollution intensive and hence it is structural changes to these sectors that will have the largest impact on a country's pollution emissions. Also, because these are the most pollution intensive sectors within each country, they are likely to face the greatest competitive pressure from low regulation sectors in the South.

Table 1
Estimation results for the air pollutants

Dependent variable	NO_x	SO_2	CO	SPM	VOC	CO_2
Y	4.57*(4.6)	6.40*(4.1)	−46.36*(−3.0)	10.4*(2.6)	−53.15*(−2.1)	2.50*(3.1)
Y^2	−0.23*(−4.2)	−0.35*(−4.2)	5.09*(3.1)	−0.57*(2.7)	5.62*(2.1)	−0.11*(−2.6)
Y^3	–	–	−0.18*(−3.1)	–	−0.19*(−2.0)	–
M	0.27*(2.6)	0.75*(3.9)	0.51*(5.0)	0.39(0.8)	0.20^+(1.6)	0.16^+(1.8)
DX	−0.027(−0.6)	0.15*(2.1)	−0.50*(−11.8)	−0.15(−0.9)	−0.12*(−2.8)	−0.052*(−2.0)
DM	−0.054(−1.4)	−0.11*(−2.0)	−0.16*(−4.0)	−0.33*(−2.0)	-0.069^+(−1.6)	0.042^+(1.6)
Trade	−0.044(−0.7)	−0.45*(−5.1)	−0.87*(−20.6)	−0.47*(−2.2)	−0.26*(−4.0)	−0.0044(−0.09)
R^2	0.39	0.72	0.60	0.77	0.43	0.46
n	234	247	221	117	208	286
Peak turn. pt. (1995 $)	$17,675	$7621	$24,744	$8650	$42,216	$63,771
Peak turn. pt.(no DM, DX)	$17,399	$5265	$24,373	$10,801	$26,735	$34,880
F-test (DM and DX)	3.76(0.15)	6.78*(0.03)	257.26*(0.00)	7.46*(0.02)	12.25*(0.00)	5.39^+(0.06)

* and + denote statistical significance at 95% and 90% confidence levels, respectively.

by trade and the pollution haven hypothesis in the EKC relationship. Second, in response to the claim that the EKC may suffer from simultaneity bias due to causality moving from environmental degradation to income, a Hausman specification test is employed to test the null of exogeneity of current income. The null of exogeneity is accepted in all cases suggesting that simultaneity bias is not present.[10] Third, in response to the claim by Stern et al. (1996) that some studies have failed to test for heteroscedasticity and autocorrelation, diagnostic tests are used which confirm the presence of both conditions. They are therefore corrected using a generalised least squares procedure. Fourth, a cubic income term has been included in Eq. (3) in response to the claim that a simple quadratic equation does not allow for the possibility of pollution beginning to increase again at high income levels. However, where the cubic term is not statistically significant (at 90% confidence level) a quadratic equation is estimated. Fifth, in order to prevent the dependent variable becoming zero or negative, Eq. (3) has been estimated in logs. Finally, in response to Ekins's (1997) and Harbaugh et al.'s (2002) concerns regarding the fragility of estimated EKCs, the estimation of EKCs for a large number of indicators will serve as a check on previous studies.

[10] Lagged income was used as the instrumental variable. Test results are available from the author.

Tables 1 and 2 provide the estimation results for the air pollutants and the water quality indicators, respectively. T-statistics are in parentheses and all turning points are in 1995 US dollars. To put these turning points in context, according to the World Bank (1999), 1997 per capita income is $35,140 in Denmark, $27,533 in the USA, $19,241 in the UK, $4514 in Brazil, $392 in India and $112 in Ethiopia (all in 1995 US dollars).

Tables 1 and 2 indicate that all of the air and water indicators, except VOC and CO, exhibit an inverted U-shaped relationship with per capita income. For VOC and CO the income cubed term is statistically significant, although both pollutants are estimated to fall at very low income levels before exhibiting an inverted U relationship for the vast majority of the income range within the sample. The results therefore provide no evidence of an N-shaped relationship between per capita income and emissions and thus emissions do not appear to rise again at high-income levels. The estimated income level at which emissions peak ('Peak turn. pt.'), as provided by the coefficients on the income terms, is within the sample income range ($1973 to $35,140) for all pollutants except VOC and CO_2.

The manufacturing share of GNP is estimated to have a positive relationship with environmental quality for 8 of the 10 environmental indicators and is significant at 90% confidence level for 7 of these 8. It would therefore appear that structural changes within the economy are at least partly responsible for the decline in emissions experienced at higher income levels.

Table 2
Estimation results for the water quality indicators

Dependent variable	BOD	Dissolved oxygen	Nitrates	Phosphorous
Y	4.1*(2.0)	−1.51*(−2.3)	4.95*(2.5)	15.1*(6.2)
Y^2	−0.22*(−2.0)	0.089*(2.5)	−0.24*(−2.2)	−0.81*(−6.2)
Y^3	–	–	–	–
M	−2.5*(−7.4)	0.32*(3.3)	1.3*(5.1)	2.1*(8.8)
DX	0.12$^+$(1.7)	−0.049*(−2.3)	0.48*(3.8)	0.52*(4.1)
DM	−0.029(−0.5)	0.11*(8.5)	0.58*(5.5)	0.56*(4.1)
Trade	0.39*(3.7)	0.090*(2.7)	0.63*(4.4)	−0.32$^+$(−1.7)
R^2	0.43	0.41	0.77	0.67
n	416	494	585	559
Peak turn. pt. (1995$)	$7034	$5614	$32,504	$10,436
Peak turn. pt. (no DM, DX)	–	$5109	$19,608	$9013
F-test (DM and DX)	3.14(0.20)	77.82*(0.00)	71.23*(0.00)	65.74*(0.00)

For dissolved oxygen the reported turning point represents the trough rather than the peak since this indicator is positively related to water quality. The expected signs of the estimated coefficients are therefore the opposite of those for the other indicators.
* and+ denote statistical significance at 95% and 90% confidence levels, respectively.

With regard to pollution haven effects, the share of dirty imports in total imports is negatively related to environmental quality for 7 of the 10 indicators and is statistically significant at 90% confidence level for 5 of these. The share of dirty exports in total exports is a positive determinant of 5 of the 10 indicators (although only 1 air pollutant) and is significant for four of these. For all five local air pollutants (NO_x, SO_2, CO, SPM and VOC) an inverse relationship is found between the imports of dirty goods from LDCs, as a share of total imports, and per capita emissions. This would seem to suggest that imports from the South are, to some extent, replacing the domestic production of pollution intensive goods. However, the share of dirty exports to the South has a positive impact on emissions for only one of these pollutants (SO_2). For the water pollutants, the share of dirty exports has a positive relationship with environmental quality for all four indicators, although the dirty import share has an inverse relationship with environmental quality for only two pollutants. These results therefore provide somewhat mixed evidence and hence it is difficult to claim that the displacement and migration of developed country dirty industries are reducing pollution overall. Nevertheless, the F-test of joint significance of the dirty trade terms (which restricts the coefficients on DX and DM to zero) is statistically significant (at 90%) for 8 out of the 10 models, suggesting that these trade terms do statistically influence air and water pollution. The economic significance of these variables is less notable, however. For each model, the estimated elasticities for DM and DX are typically the smallest of all the independent variables.

If pollution haven effects are contributing to the inverted U relationship as has been alleged by some critics of the EKC, then we would expect our estimated turning points to differ depending on whether pollution haven terms are included or not. More specifically, if this criticism is correct then the income terms in a simple EKC model should be picking up pollution haven effects and should therefore provide a lower estimated turning point than if the pollution haven effects are controlled for separately. In addition to the turning points from our main models, Tables 1 and 2 therefore also report the estimated turning points from a simpler model which does not include DX and DM. In the majority of cases the two turning points are reasonably similar, although it can be seen that for 8 of the 10 indicators the 'simple' turning point is lower than that for our full model. This is particularly notable for VOC and CO_2, the two pollutants which previously had out of sample turning points. In the simpler model the turning points are both within our sample income range. We therefore do find evidence to suggest that the basic EKC may capture pollution haven effects which contribute to the downturn in emissions at higher income levels. Once these effects are held constant, we find a higher income level is required before per capita emissions peak.[11]

The results in Tables 1 and 2 also provide compelling evidence of a positive relationship between trade openness and environmental quality for OECD countries at least. For 8 of the 10 indicators an increase in trade openness has resulted in a reduction of emissions (or an increase in dissolved oxygen levels) and is statistically significant for 6 of these 8. Thus trade openness per se appears to facilitate environmental improvement perhaps through increasing competitiveness and the efficiency of resource use.

Although not reported for reasons of space, the estimated coefficients on the year dummies show an improvement in environmental quality over time, for all pollutants. This may be due to technological advances that increase the efficiency, and reduce the cost, of abatement or due to increasing awareness of pollution issues leading to increased demand for environmental regulations.

4. Summary and Conclusions

This paper has examined the evidence for the pollution haven hypothesis and assessed the extent to which trade, through pollution haven effects and structural change, has contributed to the EKC relationship.

An analysis of net exports of pollution intensive goods relative to domestic consumption, for four developed-developing trade pairs, provided little evidence of widespread pollution havens. Rather, Figs. 2 and 3 suggest that if pollution havens have formed they are likely to have been temporary and limited to certain regions and certain sectors. However, that does not rule out the possibility that the formation of such havens may have influenced pollution emissions.

Section 3 therefore undertook an EKC analysis for 6 air pollutants and 4 water pollutants to examine the roles played by income, trade openness, structural change, and 'dirty' trade between developed and developing countries. A number of findings can be highlighted. First, for each pollutant a robust, statistically significant relationship was estimated with per capita income. For the majority of pollutants this yielded a within sample turning point. Second, the share of pollution intensive imports and exports, between OECD and non-OECD countries, appears to at least partially explain emissions and indicators of environmental quality. These pollution haven effects are not found for all pollutants, and even when found their economic significance appears limited. Estimated elasticities for the dirty trade shares are generally smaller than those for income, trade openness and the manufacturing share. Nevertheless, the air pollution emissions in particular appear to have experienced an inverse relationship with the share of pollution intensive imports from developing countries. Furthermore, estimated turning point income levels are often lower when such pollution haven effects are omitted, suggesting that such effects are captured by the income terms if not controlled for separately.

The EKC analysis also yields two other strong results. First, the share of manufacturing output in GDP generally has a positive, statistically significant relationship with pollution. Thus, the relative contraction of the manufacturing sector as a whole has proved beneficial to OECD pollution emissions. Finally, having controlled for structural change, income and possible pollution haven effects, trade openness still exhibits a negative, statistically significant relationship with pollution. To be somewhat speculative, this may be due to resource efficiencies arising from increased competitiveness or from greater access to 'greener' production technologies.

The downturn in emissions experienced at higher income levels therefore appears to be a result of the increased demand for environmental regulations and increased investment in abatement technologies (both facilitated by higher income levels), trade openness, structural change in the form of a declining share of manufacturing output, and increased imports of pollution intensive output. However, In order to ascertain whether the EKC relationship is a historical artifact or whether today's LDCs will be able to follow a similar pollution-income path it is necessary to know whether the income elasticity of demand for manufacturing products, and particularly pollution intensive products, falls as income increases. There is some evidence to

[11] In order to further investigate the linkages between income and the pollution haven variables, Eq. (3) was also estimated for each indicator with the interaction terms y*DM and y*DX included. Unfortunately, these terms were not statistically significant and signs were inconsistent across pollutants making interpretation very difficult. These results were therefore omitted.

suggest that this is the case for the basic industries, but little widespread evidence for the manufacturing sector as a whole.[12] It is therefore unclear whether today's LDCs can expect to experience a decline in manufacturing as a share of GDP, and hence can experience similar pollution-income paths to today's developed economies. If the income elasticity of demand for manufactured products does not fall with income, then the declining manufacturing share of GDP simply reflects the fact that the developed countries' demand is now being met by the developing countries. The developing countries will therefore have no one to whom this production can be passed.

Appendix A. Data Information

Tables 3 and 4

Table 3
Pollution information

Pollutant	Type	No. of countries in sample
Nitrogen oxides (NO_x)	Local air pollutant and cause of transboundary acid rain	17
Sulphur dioxide (SO_2)	As above	18
Carbon monoxide (CO)	Local air pollutant	16
Suspended Part. Matter (SPM)	Local air pollutant	8
Volatile organic compounds (VOC)	Local air pollutant	15
Carbon dioxide (CO_2)	Global air pollutant and major contributor to global warming	21
Nitrates concentrations	Water pollutant	44 rivers in 17 countries
Phosphorous concentrations	Water pollutant	42 rivers in 17 countries
Biological Oxygen Demand (BOD)	A measure of the demand placed on a river's oxygen by pollution	31 rivers in 11 countries
Dissolved Oxygen	A measure of the actual oxygen levels in a river	37 rivers in 14 countries

The sample income range for each pollutant is \$1973 to \$35,140.

[12] See, for example, Janicke et al. (1997) and Larson et al. (1986) for a discussion of why the use of basic materials (e.g. steel, cement, ammonia) may decline as an economy develops.

Table 4
Data sources for Eqs. (1), (2) and (3)

Variable	Source
Pollution	OECD (1999)
Per capita income	World Bank (1999)
Share of manufacturing in GNP	World Bank (1999)
Trade openness	World Bank (1999)
Share of dirty non-OECD imports and exports in total imports and exports	Calculated using ISIC data from the World Bank's Trade and Production Database. ISIC sectors 34, 35, 36 and 37 were classed as dirty sectors.
Trade-pair imports and exports and total imports and exports	OECD International Trade by Commodities Statistics–revisions 2 and 3
Sectoral production	United Nations Industrial Statistics Yearbooks (several volumes)

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