INTRA NATIONAL TRADE AND POLLUTION: EVIDENCE FROM THE UNITED STATES

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ABSTRACT

The environmental Kuznets curve hypothesis postulates that pollution follows an inverted-U path with economic growth. This pattern has been explained in terms of structural change in the composition of output, less pollution intensive production techniques and increased regulation at higher levels of income. Using data for 48 US states over the period 1997-2002 this study examines the relationship between income and releases of a broader set of pollutants as well as exposure to pollution by weighing chemicals by their respective toxicity. While the composition effect and regulation of pollution producing output are important determinants of production related releases per capita, the flow of goods among states significantly determines pollution. There is evidence that states can reduce releases by importing goods form other states.

INTRODUCTION

The Environmental Kuznets Curve (EKC) hypothesis predicts an inverted-U shaped relationship between a country's level of income and pollution. At low levels of income, pollution rises with increases in income until a certain income threshold is reached beyond which pollution declines. There are two broad explanations for such relationship (see Grossman and Krueger, 1995, Seldon and Song, 1994, Suri and Chapman, 1998, Barrett and Graddy, 2000). On the supply side, an increase in economic activity (scale effect) in the early stages of economic development produces an increase in pollution, while at the later stages of economic development, a change in the structure of economic activity from pollution intensive manufacturing sector to less polluting service sector (composition effect) accompanied by technological innovation in form of less pollution intensive production techniques (technique effect) leads to a decrease in pollution. On the demand side, consumers demand better environmental quality as their income increases. This is revealed through an increase in consumption of less polluting goods, relocation away from environmentally degrading areas and by demanding stricter regulation of pollution producing output by their governments.

Most of the evidence of the EKC is based on cross-country data and is limited to a small number of pollutants. Recently, attention has been given to a single country analysis (Carson et al., 1997, List and Gallet, 1999, Gawande et al., 2000, Rupasingha et al., 2004). This study examines the relationship between a broader set of pollutants as reported in the Toxic Release Inventory (TRI) and income, using data on US states over the period 1997-2002. It further examines the impact of the flow of goods and services between states, composition of output and the level of environmental regulation on per capita releases. The results indicate that states with more capital intensive production, states with greater outflow of shipments and states with less environmental regulation and lower percentage of educated population have higher air releases per capita. There is indication that air releases decrease at an increasing rate with an increase in real personal income per capita. However, the results are not robust for total (all media) releases per capita or toxicity weighted air or total releases per capita.

EMPIRICAL LITERATURE ON THE EKC

The early papers by Shafik and Bandopadyay (1992), Selden and Song (1994) and Grossman and Krueger (1995) examined a panel of countries and found an inverted-U pattern between pollution and a country's level of GDP for ambient levels of sulphur dioxide, nitrogen oxide and suspended particulate matter. The upward slope of the EKC is due to an increased level of economic activity at lower levels of income, while the downward slope of the EKC has been interpreted in light of composition and technique effects and/or consumer demand for environmental quality at higher levels of income. However, the models used in these studies are largely of a reduced form and they mainly included GDP and variables that are unlikely to be correlated with income allowing the GDP term to capture both direct and indirect effects of income on pollution. Since changes in GDP reflect changes in economic structure as well as changes in income, such models could not differentiate between the effects of structural change, technology and consumer demand for environmental quality on the income pollution relationship.

In an attempt to explain how pollution shapes with economic development, some studies controlled for the influence of other variables besides income. Panayotou (1997) controlled for the industrial structure of a country to separate the effect of production on pollution generation from the effect of income on pollution control, while Torras and Boyce (1998) and Barrett and Grady (2000) included measures of civil and political rights, literacy and economic inequality. Some studies also examined the effect of openness to trade and further the effect of shifting pollution and resource intensive production across international borders on the growth-environment relationship. The effect of openness to trade was tested by Shafik and Bandopadyay (1992) who found weak evidence that pollution is lower in more open economies. Lucas et al. (1992) found evidence that industries with higher toxic intensity tend to move to poorer countries. Low and Yeates (1992) confirmed that the export share of pollution intensive goods has risen for developing countries but declined for developed countries. On the other hand Suri and Chapman (1998) directly incorporated the shares of manufacturing goods in a country's imports and exports while Kaufman (1998) included exports of iron and steel per unit of GDP to measure the effect of spatial intensity of economic activity. Both studies found that trade significantly affected the link between income and environmental quality, although neither found a support for the EKC.

The cross-country empirical studies have been criticized on the basis of compatibility and quality of data. Stern et al. (1996) note that pollution data used in environmental Kuznets' curve studies are "notoriously patchy in coverage and/or poor in quality" (p. 1156). This is especially a problem for studies that include data from both developed and developing countries. To overcome this problem, Vincent (1997) suggested that the EKC should be studied in a context of a single country. Using data on Malaysian states, he did not find evidence of the EKC for selected air and water pollutants.

Several researchers examined the EKC using only data for the US (Carson et al., 1997, List and Gallet, 1999, Gawande et al., 2000, Rupasingha et al., 2004). Carson et al. (1997) used state level data on seven pollutants and found that all seven pollutants decreased with increasing per capita income over the period 1988-1994. Wang et al. (1998) used a cross sectional US county data and found evidence of an EKC for a measure of the assessed risk to hazardous waste exposure. List and Gallet (1999) used a panel of state level sulphur dioxide and nitrogen oxide emissions over the period 1929-1994 and found an inverted-U pattern between income and per capita emissions. Similar to Wang et al. (1998), Gawande et al. (2000) found an EKC between the number of hazardous waste sites and per capita income.

Building on the studies discussed above, this study examines whether the EKC relationship exists between income and a broad set of pollutants for US states after controlling for production differences, structure of the economy, stringency of regulation, flow of good between states and socio-economic characteristics of a state. The advantage of using US states is that they can be considered economies that are at the advanced stages of economic development and can provide better evidence whether emissions fall as income increases.

ECONOMETRIC MODEL AND HYPOTHESES TESTED

The standard reduced functional form model representing the relationship between economic growth and pollution in a country *i* is given by

$$E_{it} = a_i + \gamma_t + \beta_1 X_{it} + \beta_2 X_{it}^2 + \beta_k Z_{kit} + e_{it}$$

where *i* ranging 1,…N, represents countries; *t* ranging 1,…T, represents time; E_i represents the environmental stress variable; X_{it} is the income per capita; Z_{kit} are other variables that affect environmental quality; $\_{i}$ is the country specific effect; $\_{t}$ is the time specific effect and e_i is an error term. The relationship between income and pollution can be easily tested by examining the signs and the significance of $\_{1}$ and $\_{2}$ coefficients. If $\_{1} > 0$ and $\_{2} = 0$, pollution increases monotonically with an increase in per capita income. $\_{1} < 0$ and $\_{2} = 0$ indicates a monotonically decreasing linear relationship between income and pollution. To obtain the inverted-U shaped relationship between economic growth and pollution, $\_{1}$ must be positive and $\_{2}$ must be negative.

Most econometric studies include real GDP per capita and its square where GDP represents the scale of economic activity and the square term accounts for the structural change in the composition of the GDP, increased environmental regulation and consumer demand for environmental quality as income increases. This study directly controls for some of these effects.

To account for differences in production (composition effect) included is capital to labor ratio (KL). Antweiler et al. (2001) noted that capital-intensive industries tend to be more polluting than labor intensive industries. Therefore states with higher capital to labor ratios are expected to have greater proportion of pollution intensive industries and greater emissions of toxic chemicals.

Suri and Chapman (1998) argued that it is also important to account for the fact that pollution in one area depends on the volume of goods that embody pollution that are imported or exported from that area. To account for the flow of goods between states, the value of inbound shipments (IMPORTS) represents imports by a state while the value of and outbound shipments (EXPORTS) represents exports by a state. If states are able to export pollution, it is expected that states with greater exports will have higher levels of pollution.

The pollution haven hypothesis argues that an increase in demand for environmental quality will cause pollution and resource intensive production to move from rich countries which are expected to have higher environmental standards to poor countries with less stringent environmental regulation. A number of US studies found evidence for domestic pollution havens (Hendersen, 1996; Kahn, 1997; Becker and Hendersen, 2000). Since environmental regulation is not equally enforced across areas in the US, regulated firms are likely to move to less regulated areas. Two measures of stringency of environmental regulation are included. First is the total all media pollution abatement costs and expenditures per value added by manufacture (PACE). The second is the League of Conservative Voters score (LCV) representing the state average of senate and house votes on environmental issues and programs collected annually and published in the National Environmental Scorecard (1997-2002). LCV scores represent the sentiment of a state's population on environmental issues. It is hypothesized that states with greater pollution abatement expenditures as well as states with higher LCV scores will have lower emissions per capita.

Additional control variables include population density (POPDEN) and percentage population with bachelor degree or higher (PCTBD). It is hypothesized that pollution will be lower in more densely populated states since they tend to be more concerned with pollution. Several EKC studies found that areas with greater educational level experience less pollution due to better awareness and access to information by their citizens which allows for better political organization and lobbying power (Torras and Boyce, 1998, Wang et al., 1998, Gawande et al., 2000).

DATA AND SOURCES

The model estimated in this study represents a short panel covering the 48 contiguous states over the period 1997-2002. The dependent variables are toxic releases to air and total toxic releases to the air, water, land and underground injection wells as reported to the Toxic Release Inventory (TRI). The TRI data are maintained by the Environmental Protection Agency and include the on-site releases and the off-site transfers of some 650 chemicals reported by manufacturing facilities from industries with SIC codes 20-39. Using pounds of releases to examine potential environmental impacts assumes that all chemicals are equally toxic and that all people are equally exposed to the releases. Since exposure depends not only on the quantity discharged but also on toxicity, persistence and synergies among different substances, one way to address exposure is to create a toxicity weighted measure of releases as a sum of the pounds of releases of each chemical multiplied by its toxicity inhalation score. The toxicity score is from the EPA's Chronic Human Health Indicators used in the EPA's Risk Screening Environmental Indicators database and are based on chronic rather than acute effects. The scores exist for over 425 chemicals and increase as the potential to cause chronic harm to human health increases.

The measure of exports and imports of goods by states is from the 1997 and 2002 Commodity Flow Survey. The data are collected every five years by the Census Bureau and the Department of Transportation. The value of shipments is the market value of goods shipped from mining, manufacturing, wholesale and mail order retail establishments, as well as warehouses and managing offices of multiunit establishments. Exports represent outbound shipments in millions of dollars from the state of origin to all other states, while imports represent inbound shipments in millions of dollars from all other states to the state of destination. To create a panel data of shipments, the values for imports and exports between years 1997 and 2002 were created using linear interpolation.

The total all media pollution abatement costs and expenditures in millions of dollars are from the 1993 and 1999 Current Industrial Reports. Regional Economic Accounts published by the Bureau of Economic Analysis provided data on the real per capita income in each state measured in 2000 dollars for the years 1997-2002.

Capital to labor ratio is not available by state and a proxy variable was created. Labor is measured as the number of employees (in millions) by all manufacturing establishments, while total capital expenditure in millions of dollars serves as a proxy for the capital stock. Both variables are from the Annual Survey of Manufacture.

Educational attainment is measured as the percentage of population who are 25 years and older with a bachelor degree, while population density captures number of persons per square mile. The values for both variables are from the 1990 and 2000 Census of population. Table 1 page 114 summarizes the data definitions and sources.

Summary statistics for all variables are provided in Table 2 on page 115. Real per capita income shows great variation across states with Mississippi reporting the lowest real per capita income in 1997 ($19500) and Connecticut reporting the highest per capita income in 2000 ($42038). Vermont reported lowest air releases and total releases per capita in 2002, as well as lowest weighted air and weighted total releases per capita in 2001. Nevada reported highest total releases and weighted total releases per capita in 1998. West Virginia reported highest air release per capita in 1999 while Utah reported highest weighted air releases per capita in 1997.

RESULTS

The model relating income to pollution is estimated using feasible generalized least squares (FGLS) correcting for heteroskedasticity. This is a random effects model. This estimator was chosen over the fixed effects estimator because of variation in errors across firms and pollutants and to allow for groupwise heteroskedasticity across states, which is best handled by the FGLS estimator. The estimation results are presented in Tables 3, 4 and 5 on pages 115-119. Tables 3 and 4 show results for the full estimation. In models 1 and 2 in Table 3, dependent variables are un-weighted pounds of air emissions per capita and releases per capita, respectively. In models 3 and 4 in Table 4, dependent variables are toxicity weighted air emissions per capita and toxicity weighted releases per capita, respectively.

Models 1 and 2 in Table 3 show that air emissions and total releases are greater for states with greater capital to labor ratios which supports the results found by international studies that used this variable as a proxy for the composition effect (Antweiler et al., 2001; Cole and Elliott, 2003). However, the coefficient on the percent earnings from manufacturing sector is positive and significant in model 1 but negative and significant in model 2. This indicates that air releases per capita are higher in states with a greater concentration of a traditionally dirtier manufacturing sector which is not true for the total releases per capita. The measures of environmental regulation have a statistically significant effect on both air releases and total releases per capita. Both models show that environmental degradation is lower in states with greater LCV scores. The coefficient on pollution abatement expenditures per value added by manufacture is statistically significant only in model 1 and has a positive sign indicating that states with greater pollution abatement expenditures have higher air releases. Färe et al. (2001) propose several explanations for the relationship between emissions and pollution abatement costs. One possible explanation is that a change in the composition of the manufacturing sector of a state results in both lower emissions and lower pollution abatement costs. Since these are all media pollution abatement costs and expenditures, it is possible that they differ across media. Another explanation is that technical progress may make it possible to reduce emissions at a lower cost which would explain the positive sign on the pollution abatement cost coefficient in model 1.

Both intra-national trade variables are statistically significant in models 1 and 2. The coefficient on imports is negative while the coefficient on exports is positive indicating that states with a greater value of outbound shipments have higher air and total releases per capita, while states with greater dollar value of shipments flowing into the state from other states have lower emissions per capita. This suggests that states could reduce production related pollution by importing pollution intensive goods from other states.

The two control variables, percent adult population with a bachelor degree and population density are negative, although only the former one is statistically significant indicating that states with greater percentage of educated population have lower releases.

The coefficients on real personal income per capita and the square term are statistically significant only in model 1 where the dependent variable is air releases per capita. The coefficient on the real per capita income is negative while the coefficient on the real per capita income square is positive. This indicates that for all states air emissions per capita are declining with an increase in income at an increasing rate.

The estimated model does not have explanatory power when toxicity weighted air release or toxicity weighted total releases are considered as presented in models 3 and 4 in Table 4. Most variables, although they preserve the original signs are not statistically significant at conventional 5% or even 10% levels. Since income variables are not individually nor jointly statistically significant, models 2 through 4 in Tables 3 and 4 are re-estimated excluding the square value of real per capita income. The results are shown in Table 5.

In all models in Table 5, the coefficient on income is not statistically significant. Comparing model 1 in Table 5 with model 2 in Table 3 where the dependent variable is total releases per capita, most coefficients have the same sign and statistical significance except for the coefficient on pollution abatement costs which is no longer significant and the coefficient on the percent of earnings from manufacturing which is now negative and significant. In model 2 in Table 5 where the dependent variable is toxicity weighted air releases per capita, only the coefficient on the LVC score and the coefficient on the education variable are negative and statistically significant indicating that exposure to toxic air pollution is lower in states with a higher concern for environment by the citizens. In model 3 in Table 5, where the dependent variable is weighted total releases per capita, both trade variables are now statistically significant and indicate that states with greater imports experience lower exposure to toxic releases while states with greater exports experience higher exposure to toxic releases.

CONCLUSION

This study analyzed the relationship between environmental degradation and per capita income using data on air releases and total releases to all media as reported to the Toxic Release Inventory for the period 1997-2002. To account for the differences in exposure, the releases were also adjusted for the varying toxicity of chemicals. The focus was on the US states. Variables relating to the composition, technique and consumer demand for better environmental quality are directly incorporated in model. The results show that pollution at best declines as income increases for a broader set of air releases per capita. This is contrary to the studies that examined the relationship between income and emissions of a subset of pollutants such as ozone, nitrogen oxide, carbon dioxide and suspended particulates. There is evidence that states with greater composition of dirtier industries as measured by the capital to labor ratio have higher production related releases. Pollution is lower in states with greater percentage of educated labor force and states that pay greater attention to environmental issues as represented by the LCV score. Intra national trade in goods is important for determining pollution. There is some evidence that states with a greater dollar value of inbound shipments experience lower pollution while states with a greater dollar value of outbound shipments experience higher pollution. The results are not robust when toxicity weighted releases are considered.

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Table 1
Data definitions and sources

Variable and source	Definition
Toxic Release Inventory (TRI)	
Releases	Pounds of releases to air, water, underground injection, land and publicly owned treatment works
Annual Survey of Manufactures	
Labor	Average number of employees in all industries, 1997-2002
Capital	Total capital expenditures ($millions), 1997-2002
Value added by manufacture	($millions), 1993, 1999
BEA Regional Economic Accounts	
Real PIPC	Real personal per capita personal income in 2000 $, 1997-2002
% manufacturing earnings	Percent of all non-farm earnings from manufacturing sector, 1997-2002
Current Industrial Reports	
PACE	Total (all media) pollution abatement costs and expenditures ($millions), 1993 and 1999
League of Conservation Voters	
LCV score	State average score of senate and house votes on environmental issues and programs, 1997-2002
Commodity Flow Survey	
Imports	Inbound shipments from all other states ($millions), 1997 and 2002
Exports	Outbound shipments to all other states ($millions), 1997 and 2002
1990 & 2000 Census	
% bachelor degree	Population 25 years and older with a bachelor degree
Population density	Persons per square mile

Table 2
Summary statistics

Variable	Mean St. Deviation	Minimum Maximum
AIRREL	7.3769 (6.9166)	0.1295 42.8242
TOTREL	29.8512 (73.4852)	0.3244 711.756
TOX AIRREL	5974.706 (25472.5)	15.58952 253327.7
TOX TOTREL	372379.2 (1566626)	19.35387 1.56e+07
RPIPC	27458.93 (4246.164)	19500.86 42038.71
MFEARN	15.2222 (5.4183)	5 29
KL	17.1411 (55.8715)	4.6584 513.0457
PACE	0.0054 (.0.0087)	.00033 .06727
LCV	43.6771 (27.5579)	0 97.5
IMPT	92937 (78990.07)	6276 353640
EXPT	93386.49 (81458.68)	5414 366103
PCTBD	14.0979 (2.7832)	7.5 21.6
POPDEN	177.4781 (244.5423)	4.7 1134.4

Table 3
Regression results with un-weighted releases

	Model 1	Model 2
Variables	**AIRREL**	**TOTREL**
RPIPC	-0.0025 [a] (0.0004)	-0.0004 (0.0033)
$RPIPC^2$	3.62 E-08 [a] (5.93E-09)	7.44E-09 (4.83E-08)
KL	0.0184 [a] (0.0024)	0.1002 [c] (0.0567)
PACE	65.2731 [b] (25.8444)	-130.0122 (251.5314)
LCV	-0.0345 [a] (0.00783)	-0.2198 [a] (0.0659)
IMP	-1.14E-05 [c] (5.99E-06)	-0.0002 [b] (8.28E-05)
EXP	2.31E-05 [a] (5.87E-06)	0.0001 [c] (7.13E-05)
MFEARN	0.1716 [a] (0.0394)	-1.2879 [b] (0.5356)
PCTBD	-0.3655 [a] (0.0879)	-1.8713 [c] (1.0468)
POPDEN	-0.0005 [a] (0.0007)	-0.0053 (0.0093)

Standard deviation in parentheses. Results are obtained using the FGLS estimator and correcting for heteroskedasticity.
[a] indicates statistically significant at the 1% level;
[b] indicates statistically significant at the 5% level;
[c] indicates statistically significant at the 10% level

Table 4
Regression results with weighted releases

	Model 3	Model 4
Variables	**TOX AIRREL**	**TOX TOTREL**
RPIPC	-0.09438 (1.1243)	-17.789 (85.5853)
RPIPC^2	3.22E-06 (1.76E-05)	0.0002 (0.0013)
KL	-4.5472 (5.3866)	1049.338 (986.7755)
PACE	-2878.675 (41619.96)	-5498399 (5623351)
LCV	-22.2369 (17.3585)	-968.1399 (1426.674)
IMP	-0.009 (0.0127)	-2.7987 (1.8074)
EXP	0.0078 (0.0113)	2.4203 (1.5440)
MFEARN	-21.4622 (91.1117)	-24946.68 [b] (10477.16)
PCTBD	-441.9864 [c] (249.9187)	-12699.48 (24877.32)
POPDEN	-0.6826 (1.9887)	-177.0778 (243.2314)

Standard deviation in parentheses. Results are obtained using the FGLS estimator and correcting for heteroskedasticity.
[a] indicates statistically significant at the 1% level;
[b] indicates statistically significant at the 5% level;
[c] indicates statistically significant at the 10% level

Table 5
Regression results without income square

Variables	Model 1 TOTREL	Model 2 TOX AIRREL	Model 3 TOX TOTREL
RPIPC	-0.0003 (0.0008)	0.1377 (0.2096)	-12.7356 (19.9709)
KL	0.0963 [c] (0.0561)	-3.9643 (4.8551)	932.1162 (943.7614)
PACE	-129.2591 (230.6044)	-7027.32 (35791.73)	-5689006 (4973820)
LCV	-0.2034 [a] (0.0651)	-27.3886 [c] (16.1171)	-698.8888 (1408.722)
IMP	-0.0002 [b] (8.0E-05)	-0.0086 (0.0119	-2.8898 [c] (1.6554)
EXP	0.0001 [c] (6.9E-05)	0.005 (0.0107)	2.5195 [c] (1.4439)
MFEARN	-1.3552 [b] (0.5384)	-0.9202 (88.7237)	-26233.55 [a] (9928.895)
PCTBD	-1.7477 [c] (1.0508)	-466.3683 [c] (242.5207	-10908.79 (24135.63)
POPDEN	-0.003 (0.0098)	-0.2877 (1.8424)	-124.0614 (243.126)

Standard deviation in parentheses. Results are obtained using the FGLS estimator and correcting for heteroskedasticity.
[a] indicates statistically significant at the 1% level;
[b] indicates statistically significant at the 5% level;
[c] indicates statistically significant at the 10% level