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International Environmental Indicators: Trade, Income and Endowments

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INTERNATIONAL ENVIRONMENTAL INDICATORS:
TRADE, INCOME AND ENDOWMENTS

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"Agricultural Trade and the Environment:
Understanding and Measuring the Critical Linkages",

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The "new" economic growth theory focusses upon positive production externalities generating multiple, potential, steady state growth paths. In contrast the environmental literature frequently suggests the possibility that growth itself may exhibit negative externalities though these may be imposed upon the production process, upon human consumers or non-human life forms. Whereas the new economic growth theory has generated a spate of empirical testing, largely founded upon cross-country comparisons, potential environmental effects remain largely neglected in the empirical literature. One reason for this contrast is the availability of data.

Environmental measures are very limited in scope. Moreover, a number of the existing measures stem from simulations rather than direct observation. Nonetheless, given the importance and neglect of the topic it seems worth exploring these data while baring in mind their limitations. To the extent that the issue of reliability amounts to errors-in-measurement in the dependent environmental variables, discerning statistical patterns is made more difficult by the additional noise in the data. On the other hand, any patterns which do emerge are only likely to be biassed if the errors-in-measurement are correlated with our explanatory terms.

The objective of this paper is therefore to examine some international indices of environmental impact in relation to both macro-economic indices and information about the nature of each country. The paper is divided into six main sections. Section I briefly describes the macro economic measures adopted as explanatory variables. Sections II and III examine pooled time-series cross-country data on industrial CO2 emissions and on manufacturing emissions of toxins, water and air pollutants respectively. The remaining sections each deal with cross-country data at one point in time. In particular, Section IV addresses some issues of land use (including wilderness preservation and deforestation) and water use; Section V takes up threats to various animal species (number of species threatened, pesticide use and marine fishing); finally Section VI returns to several aspects of emissions (methane and CFC emissions, nuclear power and municipal waste). Discussions of the particular environmental measures and of the specific approaches are taken up within each section.

I. The Macro Economic Measures

In this initial exploration, the focus falls upon two sets of issues with respect to economic measures. First, although it is commonly suggested in the environmental literature that an inverse u-shaped relationship exists between environmental degradation and level of income per capita, this idea has actually not been subjected to much systematic testing. The source of data for the macro economic, explanatory variables explored in this paper is the World Bank's World Tables data discs. These files contain a number of measures of income. The Summers-Heston data on income per capita are no doubt the best international comparisons. However, this

GDP + GDP^2 + γ (growthrate)

measure is only available for a limited set of countries and years, and indeed it seems likely that this selectivity is not random (a point scarcely recognized in testing the new economic growth literature). For present purposes, the measure of income adopted is Gross Domestic Product (GDP) at factor cost, measured at constant prices in local currency units and expressed in US dollars using the 1987 conversion factor.[1] To a large extent this choice is influenced by its availability for a wide range of countries. To test for inverse u-shaped patterns, income per capita is obviously included in quadratic form. In addition, at least in the pooled time-series cross-country investigations, growth in income per capita is also included.[2]

The second macro-economic theme explored here is the consequence of outward orientation in trade. Many environmental lobby groups oppose progress toward free trade on the assumption that trade liberalization accelerates environmental damage. There is little evidence either way on this issue, despite the critical nature of the topic both for the environment and for trade policy. For present purposes, openness is simply represented by the ratio of exports of goods and services to GDP. Since it is well known that

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1. In the cross-country analyses, income per capita for 1987 is adopted, since data for more recent years are still frequently missing.

2. In the subsequent cross-country analyses this growth measure is generally excluded since, for instance, including average growth from 1980 to 1987 would have meant a significant (and probably biassed) reduction in sample size as a result of missing data.

this ratio tends to be larger for small countries, simply by virtue of their size, this same measure is also included interacted with size of population (and population included as a separate control).

II. Industrial CO2 Emissions

The Oak Ridge National Laboratory produces estimates of CO2 emissions from fossil fuel burning and from cement manufacturing for 113 countries in each year from 1970 through 1989. These estimates are generated from apparent consumption of fossil fuels and of cement production, using global average fuel chemistry data. Table 2.1 examines these data using a fixed effects model (incorporating a dummy variable for 112 of the 113 countries represented in the sample).[3]

Total annual CO2 emissions from these sources indeed at first rise with GDP per capita then subsequently tend to decline (both effects being statistically significant on a one-tail, 95 percent confidence level test). However, the implied turning point occurs at a GDP per capita of 24,568 1987 US$, which is well beyond the actual income of any country at the time. In other words CO2 emissions are estimated to continue to rise with income per capita over the range of existing incomes, though to rise less rapidly at higher incomes.

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3. Estimation of the fixed effects models in this paper is by ordinary least squares. T-statistics for a zero null hypothesis are shown in parentheses beneath coefficient estimates.

TABLE 2.1

INDUSTRIAL CO_2 EMISSIONS
Fixed Effects Time Series Model

Dependent Variable: Annual CO_2 Emissions (1000 tonnes).

	Total	Solid Fuels	Liquid Fuels	Gas Fuels	Gas Flaring	Cement Manuf.
Intercept	4428022	1070871	2335096	672597	358997	-9983
	(15.03)	(4.16)	(9.25)	(4.42)	(12.22)	(1.00)
GDP/Capita (Y) [1987 US$]	5.061	7.711	-6.260	2.360	1.129	0.111
	(2.32)	(4.04)	(3.35)	(2.09)	(5.19)	(1.51)
Y^2 /1,000,000	-103.0	-78.00	60.00	-72.10	-7.800	-5.710
	(1.70)	(1.46)	(1.16)	(2.30)	(1.29)	(2.79)
Growth in Y [%]	39.48	-21.00	70.96	-21.39	12.41	-1.888
	(0.30)	(0.18)	(0.63)	(0.32)	(0.95)	(0.43)
Exports/GDP (X)	-8323	-16510	10161	-3534	1321	255.4
	(0.72)	(1.63)	(1.02)	(0.59)	(1.14)	(0.65)
X * N interact	880.9	524.9	-334.1	179.6	534.4	-23.82
	(1.66)	(1.13)	(0.74)	(0.66)	(10.10)	(1.33)
Population (N) [Millions]	1533	1341	283.5	-105.9	-45.09	59.41
	(16.49)	(16.49)	(3.56)	(2.21)	(4.86)	(18.92)
Time [Yrs.]	-155.7	-20.73	-118.3	153.2	-185.4	15.77
	(1.01)	(0.15)	(0.39)	(1.92)	(12.02)	(3.02)
Country dummies	112	112	112	112	112	112
F statistic	5253	736	1552	860	62	764
No. obs.	1649	1651	1650	1650	1651	1651
R squared	0.99	0.98	0.99	0.99	0.83	0.98

Data source: World Resources Institute.

2GDP.

$\frac{\partial E}{\partial GDP} = 2 \cdot GDP = 0$

A similar pattern is estimated with respect to each of the component sources with the exception of liquid fuels. In the case of burning liquid fuels, projected CO_2 emissions are estimated to decline with income per capita though the rate of decline diminishes at higher incomes. It should also be noted that the CO_2 emissions from cement manufacture, according to these estimates, peak at an income of some 9,250 1987 US$ and decline thereafter.

More rapid growth in GDP per capita is not bought at a cost of higher CO_2 emissions, given income level, according to these estimates. This is both true of total emissions and of emissions from each of the separate sources.

Not surprisingly, the countries with larger populations are estimated to have significantly greater total CO_2 emissions. On the other hand, any statistical association between export to GDP ratio and CO_2 emissions is statistically very weak. If anything the estimates for total emissions suggest that a greater openness to trade is associated with smaller emissions up to a population level of just over 9 million and increase thereafter though confidence levels in this pattern are not high. The only context in which more confidence may be expressed in the association between exports and CO_2 emissions is with respect to gas flaring, which is the practice of burning off gas released during petroleum extraction: the clear positive association between export performance and CO_2 emissions from gas flaring may well reflect the rising export performance of oil exporters during the 1970s in particular.

The time trend variable included in Table 2.1 clearly shows the downward trend in the practice of gas flaring during these two decades. On the other hand, the projected CO2 emissions from burning of gas fuels and from cement manufacturing have both risen through time (even given population and any rises in income per capita). The result is that on balance total CO2 emissions from all sources in Table 2.1 exhibit only a very weak downward trend.

III. Manufacturing Toxic and Pollutant Emissions

The US EPA collects (self-reported) information on releases of toxic and other emissions from US manufacturing plants. The World Bank Industrial Pollution Projections Project team has used these data to compile average intensities of emissions per dollar's worth of output for 3-digit and 4-digit manufacturing industries. In this section, these intensities are applied to the pattern of manufacturing output, from 1970 through 1990 for 96 countries. Obviously this approach, as in the prior section on CO2 emissions, relies upon applying common intensities to production structures, irrespective of the vintage and style of technology applied and irrespective of variations in abatement procedures. Nonetheless, these are the only international data available on manufacturing emissions and consequently deserve analysis until better information is collected.

TABLE 3.1

MANUFACTURING TOXIC AND POLLUTANT INTENSITY
Fixed Effects Time Series Model

Dependent Variable: Emission Flows
(lbs. per year per US$million of manufacturing output)[a].

	All Media		Water Pollutants	
	Total Toxic Release	**Bioaccum Metals**	**Biochem Oxygen Demand**	**Suspend Solids**
Intercept	-20422 (2.97)	45.91 (0.04)	-42.70 (0.46)	-569.1 (5.24)
GDP/Capita (Y) [1000 1987 US$]	87.31 (1.75)	20.57 (2.78)	0.284 (0.43)	2.954 (3.76)
Y^2	-4.140 (2.50)	-1.643 (6.69)	-0.008 (0.38)	-0.165 (6.31)
Growth in Y [%]	-3.914 (1.32)	-0.144 (0.33)	-0.003 (0.08)	0.015 (0.32)
Exports/GDP (X)	641.7 (2.49)	-54.78 (1.43)	-7.412 (2.15)	-8.138 (2.00)
X * N interact	37.77 (3.46)	3.967 (2.45)	0.070 (0.48)	0.207 (1.20)
Population (N) [Millions]	0.094 (0.05)	0.070 (0.27)	-0.020 (0.86)	-0.027 (0.99)
Time [Yrs.]	12.23 (3.39)	0.207 (0.39)	0.033 (0.68)	0.310 (5.44)
Country dummies	95	95	95	95
F statistic	220	429	50	3523
No. obs.	1249	1249	1249	1249
R squared	0.95	0.97	0.82	0.86

Data source: World Bank Estimates.
a. Water pollutant emissions are measured per day.

TABLE 3.1 (continued)

MANUFACTURING TOXIC AND POLLUTANT INTENSITY
Fixed Effects Time Series Model

Dependent Variable: Emission Flows
(lbs. per year per US$1000 of manufacturing output[b]).

	Air Pollutants						
	Suspended Particles	**SO2**	**NO2**	**Fine Partic PM10**	**Lead**	**Volat. Organ. Comps.**	**CO**
Intercept	-8.369	-53.39	6.487	-5.625	10.97	-0.827	-15.48
	(1.49)	(5.95)	(0.80)	(1.98)	(3.64)	(0.17)	(1.29)
GDP/Capita [1000 '87$]	-0.053	-0.072	-0.264	-0.011	-0.034	0.082	-0.040
	(1.29)	(1.11)	(4.48)	(0.53)	(1.54)	(2.36)	(0.46)
Y^2	-0.000	-0.004	0.007	-0.000	-0.001	-0.002	-0.007
	(0.10)	(1.63)	(3.45)	(0.00)	(0.66)	(1.58)	(2.55)
Growth in Y [%]	-0.001	0.003	0.003	-0.001	0.000	-0.002	-0.004
	(0.35)	(0.71)	(0.73)	(0.52)	(0.24)	(1.07)	(0.74)
Exports/GDP	-0.541	-0.490	-0.678	-0.376	-0.103	0.650	0.026
	(2.57)	(1.45)	(2.22)	(3.54)	(0.91)	(3.61)	(0.06)
X * N inter.	-0.003	0.018	-0.003	-0.002	0.014	0.005	0.026
	(0.34)	(1.28)	(0.24)	(0.41)	(2.87)	(0.67)	(1.37)
Population [Millions]	0.001	-0.002	-0.004	0.001	0.000	0.001	0.001
	(0.75)	(0.68)	(1.85)	(0.75)	(0.22)	(1.17)	(0.46)
Time [Yrs]	0.006	0.032	0.001	0.003	-0.005	0.002	0.012
	(1.90)	(6.71)	(0.23)	(2.11)	(3.11)	(0.77)	(1.85)
Country dum.	95	95	95	95	95	95	95
F statistic	38	126	80	36	366	116	181
No. obs.	1249	1249	1249	1249	1249	1249	1249
R squared	0.77	0.92	0.88	0.76	0.97	0.91	0.94

Data source: World Bank Estimates.
b. Lead emissions are measured in lbs. per year per US$million.

As in the previous section, a fixed effects model, with an annual time trend plus dummy variables representing 95 of the 96 countries in the sample, is applied to these data. The results are presented in Table 3.1. Three classes of emission measures are available: total toxin releases (of which bioaccumulative metals are a subset), two types of water pollutants and seven air pollutants. Each of these is examined separately in Table 3.1 using a common simple model identical to that applied in Section II.

In the cases of total toxic releases, bioaccumulative metals, and suspended solid water pollutants, emission intensities at first rise with the level of income per capita then decline at higher incomes, (given other factors in the model held constant). The estimated turning points in these patterns range from some 10,500 1987 US$ per capita in the case of total toxins to 6,300 1987 US$ in the case of suspended water pollutants. Among the air pollutants, volatile organic compound releases also initially rise with income per capita then tend to decline, but in this case the estimated turning point is not reached until an income per capita of over 20,000 1987 US$ which is beyond the range of any country at that time. Nitrogen dioxide emissions exhibit the opposite pattern, initially declining with income per capita then rising, though again the implied turning point is beyond the sample range, and similarly, carbon monoxide emission intensities decline significantly across the entire income range. Suspended particles in the air, sulphur dioxide emissions and releases of lead into the atmosphere all tend to decline in intensity as income per capita rises, though statistical confidence in these effects is somewhat weaker.

On the other hand, these data do not indicate any clear tendency for more rapidly growing economies to exhibit more emission intensive manufacturing sectors, given income levels.

Do more open economies possess more emission intensive manufacturing sectors? The results are mixed, based upon the measure of openness adopted here, namely the ratio of exports to GDP and its interaction with population size. Total toxic release intensity is estimated to rise significantly with respect to export propensity irrespective of population size.[4] Volatile organic compound air pollutants also tend to rise with export propensity and carbon monoxide displays a similar, though statistically much weaker, pattern. Bioaccumulative metals, sulphur dioxide, and lead released into the atmosphere all tend to decline with export propensity among countries with smaller populations then to rise with export intensity after a critical population size of 14, 27 and 7 million people respectively. In contrast, the remaining five releases (both water pollutant categories, suspended and fine

4. This result contrasts with earlier results obtained by the author in conjunction with David Wheeler and Mala Hettige, in which the Dollar index of price distortion was adopted as a measure of openness and an earlier set of estimates of toxic emission intensities deployed. The reason for this contrast requires further investigation.

particles in the air, plus nitrogen dioxide) all decline significantly as export propensity rises, irrespective of population size.

Population size itself has little direct effect upon emission intensities other than through any interactions with export propensity already discussed. However, it is disturbing to see the statistically significant, positive trend effect estimated on six of the emission intensities.[5]

IV. Land and Water Use

The remaining indices of environmental impact examined in this paper are available at one point in time for a subset of countries. So far the effects of individual countries upon the outcomes have effectively been buried in the fixed effects approach of representing each country with a dummy variable. In the remainder of the paper this is no longer the case. Instead, the association between environmental outcomes and the various characteristics of the sampled countries will be examined directly. In particular, the results are typically presented in at least two steps. At first the association between the environmental measure and the economic measures already adopted in the prior two sections is estimated without controlling for country endowments, geography, or other

5. This is based upon a five percent one-tail test. The six are total toxic release and suspended solids in water, plus suspended particles, sulphur dioxide, fine particles, and carbon monoxide air pollutants.

characteristics.[6] In the second step these latter measures are also included, to estimate the extent to which associations with the economic measures may simply reflect a common correlation with the underlying country characteristics. In a number of instances it proves instructive to present results introducing the country characteristics in stages, in some cases to bring out important interactions between the characteristics themselves, and in other cases because limited data availability on some of the characteristics severely alter the sample size.

In this first section based on cross-sectional results, some measures of land and water use are examined, turning first to preservation of wilderness areas.

Wilderness

The World Resources Institute data set reports the result of examining aerial photographs for wilderness areas. For this purpose a wilderness area is defined as a minimum area of 4000 sq. kms. showing no evidence of human development. These measures are

6. The rate of economic growth is omitted from the cross-sectional results for two reasons: in general, if these measures are included they prove to have effects statistically indistinguishable from zero; second, the measure of growth adopted is the average annual growth from 1980 through 1987, and this is not available for a substantial subset of the countries because of missing income data in some portion of the period.

examined in Table 4.1.[7]

Total wilderness area in each country at first rises then declines with income per capita, with an estimated turning point at 11,738 1987 US$, if no country properties are included in the regression. In other words, it is the middle income countries which posses the largest wilderness areas. In this first equation in Table 4.1, it is also found that wilderness area declines across countries as the propensity to export rises -- suggesting that outward orientation in exports is associated with smaller areas of wilderness preserved.

However, it must be remembered that these initial results reflect nothing of the geography of the countries in question. The second equation in Table 4.1 includes the total land area of each country in question, as well as some aspects of the nature of that land plus population density measures.

7. All cross-country results reported in this paper are obtained by ordinary least squares. T-statistics for a zero null hypothesis are again reported in parentheses, and these are derived using White's, heteroscedasticity robust, measure of standard errors.

TABLE 4.1.WILDERNESS
Dependent Variable: Wilderness Area. (1000 ha).

Intercept	41542	-584860	-474780	-533120	-232590
	(3.37)	(9.36)	(6.72)	(5.47)	(3.67)
GDP/Capita [87 US$] (Y)	10.40	31.55	29.58	59.98	20.33
	(1.49)	(3.24)	(2.95)	(3.41)	(2.71)
$Y^2/1000$	-0.443	-9.197	-7.817	-16.75	-5.045
	(1.61)	(3.17)	(2.62)	(3.36)	(2.31)
Exports/GDP (X)	-103690	93311	94951	71962	42534
	(1.99)	(3.79)	(3.39)	(4.91)	(3.08)
X * N interact	-1528	-3067	-3419	-2296	-2613
	(1.12)	(3.04)	(2.16)	(2.11)	(6.65)
Population [Mill] (N)	73.61	-56.15	7.292	-306.2	-64.44
	(0.69)	(1.45)	(0.05)	(1.57)	(4.47)
Total Land Area [1000 ha]		0.725	0.774	0.741	0.290
		(9.09)	(6.35)	(7.91)	(4.96)
Frac. Area Arid		6092	9122	13658	5759
		(0.98)	(0.83)	(1.72)	(1.87)
Frac. Semi-Arid		-15335	9384	-4547	-982.7
		(0.38)	(0.16)	(0.06)	(0.02)
Frac. Cold		89507	93999	34412	53088
		(3.09)	(2.25)	(0.46)	(1.70)
Portion Tropical		539610	423220	475410	208860
		(8.69)	(5.22)	(5.30)	(3.63)
Portion Subtrop.		510410	395180	447230	194040
		(7.51)	(4.24)	(5.60)	(3.68)
Closed Forest [1000 ha]		-0.977	-1.011	-0.499	-0.270
		(5.89)	(5.86)	(2.52)	(2.64)
Pop. Density [No./ha]		34625	45244	32940	16126
		(3.02)	(2.76)	(1.62)	(1.98)
Pop. Urban (%)		-153.1	-127.1	-179.4	-23.19
		(2.47)	(1.76)	(1.50)	(0.54)
Arable Area [1000 ha]			-0.279		
			(0.40)		
No. Cattle [1000]			0.009		
			(0.02)		
No. Sheep [1000]			-0.936		
			(1.48)		
No. Goats [1000]			0.234		
			(0.35)		
Roads [km/1000 sq km Land]				0.592	
				(1.11)	
Rail [km/1000 sq km Land]				286.1	
				(0.25)	
Number Cars [1000]				-11.62	
				(3.73)	
Rndwd prod. [1000 cub mt]					0.380
					(2.43)
Rndwd export [1000 cub mt]					-0.947
					(4.93)
Sum Sq. Res.[E10]	46.1	0.367	0.327	0.140	0.090
No. obs.	69	39	38	25	31
Adj. R squared	-0.00	0.91	0.90	0.91	0.95

Data source: World Resources Institute.

The inverse u-shape of wilderness area with respect to income level is robust to inclusion of these country characteristics though the turning point is considerably lower once the country characteristics are incorporated (1,715 1987 US$). However, the pattern with respect to export propensity alters in a critical way once these country characteristics are incorporated. In particular, in the second equation in Table 4.1 the area of wilderness actually rises with overall export propensity. Only for more populous countries, with more than 30 million people, do these results now indicate declining wilderness preservation as export orientation increases.

Turning to the country characteristics themselves in Table 4.1, not surprisingly it is found that it is countries with larger land areas which preserve the most wilderness, other things equal.[8] Two measures of the nature of the land/climate are available for present analysis. The World Resources Institute data base reports the fraction of land area which is arid, semi-arid, humid and cold (based on length of growing period). In addition, the same data base reports portion of land area which is tropical, subtropical and temperate (depending upon monthly mean temperature). In both cases, one category is dropped (humid from the former and temperate

8. The magnitude of this estimated association is surprisingly large and in future work one may wish to allow for more nonlinearity in this association. Future work should also include an analysis of the fraction of land area preserved as wilderness, and not merely the absolute amount as here.

from the latter) as the reference point in Table 4.1. Countries with a larger fraction of their land which is arid or semi-arid are found neither to have more nor less wilderness preserved than are humid areas, given the other factors included in the regressions. However, countries with a larger fraction of their land reported cold do tend to preserve more wilderness. Countries which are more tropical or subtropical possess substantially larger wilderness areas than do the temperate areas, given their income levels.

Possessing larger areas of closed forest is found to be associated with less preservation of wilderness area, other things equal. It is not altogether clear what this result reflects, but it suggests that forestry activities are commonly not consistent with wilderness preservation -- a point to which we shall return in a moment.

One might think that it is the pressure of human population on the land which results in loss of wilderness. It is therefore intriguing to find that countries with higher population relative to land area actually preserve larger areas of wilderness. On the other hand, where this population pressure translates into a larger fraction of the population in urban areas (definition of which unfortunately varies from country to country) smaller areas of wilderness do remain.

Man's agricultural activities may well be thought to threaten the wilderness. To examine this the third equation in Table 4.1 adds in measures of total arable land in each country as well as the numbers of cattle, goat and sheep kept as livestock. None of these has a significant effect in reducing the extent of wilderness, given the other variables included. Nor does the inclusion of these measures reduce the effect of greater population density being associated with larger extent of wilderness.

Another hypothesis explored in Table 4.1 is that transportation pressures result in loss of wilderness. However, the inclusion of road and rail density measures proves largely irrelevant to the extent of wilderness in the fourth regression in Table 4.1. In contrast, it is interesting to note that more automobiles are associated with significantly less wilderness preservation. Obviously the rich countries have far more cars, yet the observed decline in wilderness at higher income levels is (if anything) greater with the inclusion of cars.

In the final equation in Table 4.1, some additional measures of forestry as a threat to wilderness preservation are examined. Countries with higher total roundwood production actually tend to possess larger areas of wilderness (though this effect is insignificant unless roundwood exports are also included). On the other hand, countries which export large amounts of roundwood, (whether given roundwood production as in Table 4.1 or not), retain significantly smaller areas of wilderness. One cannot discern causality from such studies, but these results at least suggest that roundwood export industries may pose a significant threat to the survival of the wilderness.

Deforestation

Closely connected with this is the rate of deforestation occurring. The World Resources Institute data on average annual deforestation from 1981-85 are largely derived from FAO data which have frequently been disputed. Nonetheless, once again, these are the best data available and they are therefore examined in Table 4.2 with perhaps a special word of caution with respect to reliability.

TABLE 4.2.DEFORESTATION

Dependent Variable: Total Annual Average Deforestation (1000 ha).

Intercept	108.0	-6180	-7037	10181	5378	-3672
	(2.25)	(1.76)	(1.60)	(1.95)	(1.12)	(0.67)
GDP/Cap [87 US$]	0.532	0.174	0.166	0.083	0.243	0.348
	(1.75)	(2.07)	(1.83)	(1.76)	(2.03)	(3.11)
Y^2/1000	-0.136	-0.048	-0.047	-0.026	-0.100	-0.110
	(1.80)	(2.04)	(1.87)	(1.87)	(2.40)	(3.08)
Exports/GDP	-833.8	-366.3	-278.7	-164.6	-387.4	-576.7
	(1.72)	(3.36)	(2.23)	(2.98)	(1.93)	(3.61)
X * N interact	9.499	11.94	9.176	34.14	8.712	10.61
	(1.01)	(2.22)	(1.59)	(4.85)	(0.89)	(1.41)
Pop. [Mill]	-0.348	-1.219	-1.178	-5.670	1.214	-1.931
	(0.38)	(3.23)	(3.07)	(8.96)	(0.90)	(7.26)
Frac. Area Arid		-67.70	-158.0	19.57	-30.26	-143.1
		(1.89)	(2.95)	(0.57)	(0.46)	(2.69)
Frac. Semi-Arid		377.4	269.7	-93.16	-184.4	199.2
		(1.81)	(1.00)	(0.38)	(0.74)	(0.65)
Frac. Cold		8.567	110.0	35.55	68.00	-161.6
		(0.05)	(0.60)	(0.16)	(0.24)	(0.72)
Port. Tropical		6247	7060	-10135	-5191	3745
		(1.78)	(1.61)	(1.94)	(1.20)	(0.69)
Port. Subtrop.		6232	7022	-10145	-5277	3813
		(1.77)	(1.59)	(1.95)	(1.22)	(0.69)
Clos. For. [Mill ha]		6.446	4.467	2.393	6.745	4.811
		(14.92)	(3.04)	(5.90)	(3.43)	(3.36)
Land Area [Mill ha]			0.872			
			(1.54)			
Pop. Density [No./ha]			-7.697			
			(0.91)			
Pop. Urban (%)			0.506			
			(0.63)			
Arable Area [1000 ha]				-0.001		
				(0.20)		
No. Cattle [1000]				0.018		
				(4.39)		
No. Sheep [1000]				-0.007		
				(1.18)		
No. Goats [1000]				-0.004		
				(0.74)		
Roads [km/1000 sq km Land]					-0.007	
					(1.22)	
Rail [km/1000 sq km Land]					-4.905	
					(1.72)	
Number Cars [1000]					-0.016	
					(0.30)	
Rndwd. prod. [1000 cub mt]						0.003
						(1.17)
Rndwd. export [1000 cub mt]						0.000
						(0.00)
Sm.Sq.Res.[E06]	5.571	0.823	0.775	0.430	0.351	0.588
No. obs.	64	61	60	58	32	44
Adj. R squared	0.19	0.86	0.86	0.92	0.91	0.88

Data source: World Resources Institute.

Whereas the extent of wilderness preserved at first rises with income per capita then declines at higher income levels the reverse is true with respect to forest preservation. Deforestation here refers to complete transfer from forest cover to alternative use and does not include partial logging. This rate of deforestation initially increases with income levels then declines at higher incomes. This is true no matter whether country characteristics are included or not in Table 4.2, with an estimated peak of deforestation at an income level of 1,956 1987 US$ in the first regression.

The results in Table 4.2 indicate a rate of deforestation which declines with general openness with respect to exports at least among countries with smaller populations. For instance, in the first regression, in which no country characteristics are incorporated, the decline in deforestation with respect to export propensity continues up to a population level of some 88 million, thus excluding all but the largest countries (such as Brazil and Indonesia). This pattern proves robust once other country characteristics are included, though the turning point occurs at somewhat lower population levels (at 31 million in the second regression, for instance).

Countries with more arid land have smaller areas of ongoing deforestation than do the more humid areas, while semi-arid lands exhibit greater extent of deforestation. (Both of these differences are statistically significant on a 90 percent confidence level, two-tail test, at least in the second regression in Table 4.2). On the other hand cold zones do not differ significantly from humid areas. Whether the tropical and subtropical zones are deforesting more rapidly, as in the second equation, depends to some extent upon what else is held constant. In particular, once arable and livestock measures are incorporated in the fourth equation the signs on these latter differences reverse: in other words this suggests that the extent of agriculture (and perhaps cattle in particular, rather than arable activities, from the results in Table 4.2) may be a critical factor in why the rate of deforestation in the tropics is greater.

Not surprisingly, it is the countries which possess larger closed forests which are experiencing the largest extent of deforestation. However, at least in the results from this simple additive specification suggest that each additional million hectares of closed forest adds far less than 10 thousand hectares of average annual deforestation, (other things constant). More generally it seems that countries with larger land areas are experiencing more extensive deforestation, even given the extent of closed forest, though the statistical confidence in this pattern is weaker.

Interestingly, there is no sign in these data that population pressure on the land, either in general or in the form of urbanization has any significant consequence for deforestation.

Moreover, this remains true through any indirect effect of population on the extent of arable farming or even the various transport measures explored in the fourth and fifth regressions respectively.

Most importantly, there is no sign in these data that either the extent of roundwood production or its export has any detrimental effect upon the extent of deforestation, (other things equal).[9] Presumably this is largely a consequence of the definition of deforestation adopted in these data, namely the total deforestation of an area, whereas logging activities must typically result in partial logging only. Combined with the results on the wilderness this indicates that roundwood export may pose a threat to virgin forest and to the wilderness more generally, but not to the total extent of forest surviving.

Freshwater

Freshwater resource diminution is a topic of severe environmental concern. The data on freshwater use in various countries are partly a result of direct reporting and partly a result of simulated use. Their analysis is taken up Table 4.3.

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9. These observations remain correct if production and export are entered individually within the last regression in Table 4.2, though the effect of production in increasing deforestation does become somewhat stronger statistically in this specification.

TABLE 4.3
WATER WITHDRAWAL

Dependent Variable: Total Annual Water Withdrawal. (km^3).

Intercept	-16.68	-5.202	-4.214	33.25
	(2.16)	(0.58)	(0.61)	(1.49)
GDP/Capita (Y)	2.195	3.907	2.007	0.519
[1000 1987 US$]	(2.04)	(2.91)	(1.72)	(0.49)
Y^2	-0.057	-0.146	-0.083	-0.030
	(0.87)	(2.73)	(1.68)	(0.76)
Exports/GDP (X)	22.67	18.68	-1.593	-43.80
	(1.37)	(0.94)	(0.16)	(1.44)
X * N interact	-4.219	-5.298	-1.937	-1.995
	(1.79)	(2.40)	(1.63)	(3.79)
Population (N)	1.681	2.125	1.006	1.014
[Millions]	(2.63)	(3.34)	(3.93)	(6.93)
Population Urban (%)		-0.171	0.025	-0.136
		(1.47)	(0.37)	(1.02)
Frac. Population Cities		0.012	0.072	-0.065
		(0.22)	(1.21)	(0.49)
Internal Water Available		-0.022		
[Cubic kms]		(1.40)		
Total Water Available			-0.013	-0.018
[Cubic kms]			(3.79)	(2.59)
Arable Area [mill ha]				0.503
				(1.14)
No. Cattle [mill]				0.056
				(0.12)
No. Sheep [mill]				-0.092
				(0.91)
No. Goats [mill]				-2.106
				(4.87)
Sm.Sq.Res.[E05]	0.611	0.489	0.049	0.025
No. obs.	78	70	36	29
Adj. R squared	0.72	0.76	0.66	0.75

Data source: World Bank Estimates.

Not surprisingly, total annual withdrawal of freshwater is greater the larger the population of a country. Freshwater use also rises with income per capita though the estimates in Table 4.3 also show a declining absolute use at very high income levels at least after controlling for water availability in the second and third equations.

The economies with greater export propensities generally tend to use lesser amounts of freshwater, according to the estimates in Table 4.3.[10]

The data offer no sign that greater concentration of the population in urban centers or in cities (urban areas of more than 2 million people) places any greater pressure on freshwater use. If anything there is very weak evidence here to suggest that urbanization (though not cities) may offer some scale economies in freshwater use.

It seems an important source of the global pressures on freshwater is the concentration of greater use in areas with smaller endowments. This turns out to be true in Table 4.3 no matter whether a measure of only nationally available renewable water resources is adopted or of total water resources available, the

10. The only exception is in the first equation, which does not allow for water availability, wherein there is a weak tendency for water use to rise with export propensity up to a population level of about 5.4 million declining thereafter.

latter including reported river flows from abroad.

International estimates of freshwater use show two-thirds of this being for agriculture and one quarter for industry. However, when total arable area and number of livestock are included in the fourth regression in Table 4.3, no evidence is found supporting pressure on water use from agriculture on average, though the role of irrigation remains to be examined in this context.

V. Threats to Species

This section examines international data on four aspects of threat to species: marine catch, the use of pesticides, and direct indicators of the numbers of various species threatened.

Marine Catch

It is not obvious to what extent marine fishing in general poses an immediate threat to marine species, though whaling certainly appears to do so, and tuna fishing has been deemed a threat to other marine mammals. Examination of specific types of fishing is not possible here, but a more general look at total marine catch is taken up. The World Resources Institute data on average annual marine catch are derived largely from FAO data. They refer to the total weight of fish and other marine life caught by a country's fleet anywhere in the world. Some results based on these data are presented in Table 5.1.

TABLE 5.1

MARINE CATCH

Dependent Variable: Total Average Annual Marine Catch.
(1000 tonnes)

Intercept	267.1 (1.47)	154.7 (0.90)	128.8 (0.84)	549.1 (1.11)	90.09 (0.60)
GDP/Capita (Y) [1987 US$]	-0.240 (1.41)	-0.311 (1.80)	-0.294 (1.62)	-0.564 (2.03)	-0.344 (1.87)
$Y^2/1000$	0.022 (1.70)	0.024 (1.92)	0.023 (1.75)	0.042 (1.94)	0.026 (1.97)
Exports/GDP (X)	-392.0 (1.03)	-8.348 (0.02)	78.00 (0.26)	-574.7 (0.55)	63.77 (0.17)
X * N interact	74.31 (1.78)	58.97 (1.69)	53.15 (1.30)	52.13 (1.24)	54.48 (1.59)
Population (N) [Millions]	-1.154 (0.35)	-1.037 (0.38)	-1.894 (0.85)	2.076 (0.54)	-1.243 (0.46)
Exclusive Economic Zone [1000 Sq km]		0.219 (1.68)	0.151 (0.86)	0.142 (0.71)	0.214 (1.84)
Meat Output [1000 tonnes]			0.061 (0.79)	0.014 (0.12)	
Average Annual Fresh Water Catch [1000 t]			0.615 (0.74)	0.722 (0.75)	
Aquaculture Production [1000 tonnes]				-5.003 (1.07)	
Dummy if Offshore ONG Production					411.1 (1.40)
Sm.Sq.Res.[E08]	0.998	0.868	0.851	0.684	0.844
No. obs.	81	78	76	52	78
Adj. R squared	0.40	0.46	0.45	0.48	0.46

Data source: World Resources Institute.

Unlike many of the other measures examined in this paper, the total marine catch tends to show a weak u-shape with respect to income per capita. In other words, the marine catch is lowest among the middle income countries, turning upward at an income level of about 5,500 1987 US$ according to the first regression formulation reported in Table 5.1 (though statistical confidence levels in these patterns is not high).

Unfortunately, data on fish exports are not readily available for present purposes. However, any association between marine catch and exports more generally proves statistically fairly weak though if anything the association does tend to be positive.

All but the first regression in Table 5.1 include the area of the exclusive economic zone attributed to each country. In the various specifications this tends to have a positive coefficient -- larger zones generate larger catches -- but the association is quite weak, no doubt in part because of fishing in international waters.

The data on meat output, freshwater catch and aquaculture production (available for only a subset of countries) are examined in the third and fourth regressions in Table 5.1. There is no systematic evidence that any of these alternatives offers a significant reduction in the level of marine catch. Perhaps this is to be expected to the extent that these protein sources are all tradeable and consequently enhanced production of one need not alter local consumption and production of the other.

Lastly, Table 5.1 reports a regression incorporating a dummy variable for whether the country has offshore production of either oil or natural gas. This measure offers no evidence that these offshore activities result in any reduction in the rate of marine catch, but rather the reverse.

Pesticide Use

Pesticide use poses an obvious threat to species deemed to be pests. To what extent pesticide use poses a threat to other species (including mankind), both directly and through the mutation of pests, remains controversial. All we are able to examine here are the reported data on pesticide use for each country, with results presented in Table 5.2.

TABLE 5.2
PESTICIDE USE

Dependent Variable: Active Ingredient in Pesticide Used (tonnes)

Intercept	11199 (2.20)	-23188 (0.88)
GDP/Capita (Y) [87 US$]	8.304 (4.06)	13.29 (2.45)
$Y^2/1000$	-0.302 (4.46)	-3.874 (2.04)
Exports/GDP (X)	-71742 (2.64)	-11127 (1.79)
X * N interact	728.9 (0.93)	14.59 (0.46)
Population (N) [Millions]	75.76 (0.51)	-20.60 (0.49)
Frac. Area Arid		5701 (1.56)
Frac. Semi-Arid		-9057 (0.98)
Frac. Cold		-28159 (1.64)
Portion Tropical		18775 (0.73)
Portion Subtrop.		17388 (0.63)
Closed Forest [1000 ha]		0.069 (2.57)
Arable Area [1000 ha]		0.348 (1.32)
No. Cattle [1000]		-0.084 (0.56)
Urban Population [%]		53.59 (1.46)
Sum Sq. Res.[E09]	107.5	0.565
No. obs.	66	37
Adj. R squared	0.26	0.77

Data source: World Bank Estimates.

The first regression again presents an estimate of the basic economic model without inclusion of any country characteristics. Once again an inverse u-shape pattern with respect to income per capita is found, with pesticide use rising up to an income of 13,750 1987 US$ then declining. Pesticide use also declines significantly among countries with higher overall export propensity (with only a very weak tendency to rise beyond a population level of 100 million). Similar patterns are found even when selected country characteristics are included in the second regression though the estimated turning points alter (to 1,715 1987 US$ in income and to a population level over 700 million).

Not surprisingly, pesticide use is influenced by climatic zone with somewhat greater use in arid areas and lower use in cold zones relative to the humid regions. Given these zones and other factors held constant in the second equation in Table 5.2, the tropics and subtropics do no differ significantly in their use of pesticides relative to temperate zones. On the other hand, countries with large closed forest areas do apply significantly larger amounts of pesticides.

Any evidence that agricultural activities increase pesticide use on average, given our economic controls and geographic factors, is very weak at best. There is a slight positive association with the extent of arable area in the specification reported in Table 5.2 though no positive association is found with size of cattle herd (nor with sheep or goats -- a result not reported in the table).

Some uses of pesticides are in urban areas, and a positive association does tend to emerge between proportion of the population residing in urban areas and total pesticide use, but this association is again statistically, relatively weak.

Species Threatened

Biodiversity is an important component of the environmental dialogue, including issues of implied threat from international trade though little systematic evidence seems to have emerged in this regard to date. The World Resources Institute reports the number of full species globally threatened (including endangered, vulnerable and rare species), by major species class, as of 1990. These data form the dependent variables studied in Table 5.3.

TABLE 5.3
SPECIES THREATENED: FRESHWATER FISH

Dependent Variable: Number of Species Threatened

Intercept	2.819 (1.67)	-6.301 (1.92)	-46.17 (1.70)
GDP/Capita (Y) [1000 '87 US$]	0.849 (1.16)	-0.816 (1.69)	12.22 (4.00)
Y^2	-0.010 (0.28)	0.034 (1.89)	-3.000 (3.35)
Exports/GDP (X)	-16.38 (1.56)	16.65 (2.70)	-17.40 (3.81)
X * N interact	0.550 (1.19)	-2.567 (4.53)	0.058 (0.23)
Population (N) [Millions]	0.010 (0.12)	0.800 (5.55)	0.040 (0.66)
No. Species Known		0.011 (2.02)	0.000 (0.05)
Frac. Area Arid			-0.852 (0.50)
Frac. Semi-Arid			-22.34 (2.03)
Frac. Cold			44.61 (2.45)
Portion Tropical			47.39 (1.76)
Portion Subtrop.			65.22 (2.39)
Average Annual Fresh Water Catch [1000 t]		-0.053 (1.35)	-0.006 (0.89)
Sum Sq. Res.	31700	3954	108
No. obs.	102	44	27
Adj. R squared	0.10	0.83	0.74

Data source: World Resources Institute.

TABLE 5.3 (continued)
SPECIES THREATENED: AMPHIBIANS

Dependent Variable: Number of Species Threatened

Intercept	0.467 (1.80)	0.085 (0.08)	-0.385 (0.61)	-0.003 (0.00)
GDP/Capita (Y) [1000 '87 US$]	0.247 (2.42)	0.351 (2.10)	0.240 (1.79)	0.100 (0.56)
Y^2	-0.007 (1.60)	-0.010 (1.90)	-0.008 (1.41)	-0.002 (0.34)
Exports/GDP (X)	-2.525 (1.90)	-3.545 (2.53)	-1.064 (0.72)	-1.320 (0.80)
X * N interact	-0.001 (0.01)	0.014 (0.24)	0.022 (0.33)	0.008 (0.12)
Population (N) [Millions]	0.009 (1.00)	0.007 (0.85)	-0.024 (4.07)	-0.015 (1.85)
No. Species Known		0.006 (0.86)	0.004 (1.64)	0.002 (1.00)
Arable Area [mill ha]			0.092 (3.85)	0.088 (3.45)
Closed Forest [mill ha]			-0.028 (4.35)	-0.014 (3.64)
Roundwood prod. [mill cub mt]			0.026 (2.19)	
Roundwood expt. [mill cub mt]				0.382 (1.98)
Sum Sq. Res.	428.9	384.2	91.9	91.0
No. obs.	102	46	43	40
Adj. R squared	0.20	0.17	0.78	0.77

Data source: World Resources Institute.

TABLE 5.3 (continued)
SPECIES THREATENED: REPTILES

Dependent Variable: Number of Species Threatened

Intercept	3.269 (4.17)	-0.675 (0.62)	0.330 (0.25)	0.613 (0.41)
GDP/Capita (Y) [1000 '87 US$]	-0.098 (0.58)	0.028 (0.17)	-0.051 (0.48)	-0.160 (0.90)
Y^2	0.001 (0.07)	0.001 (0.13)	-0.001 (0.18)	0.004 (0.60)
Exports/GDP (X)	-2.683 (1.14)	0.091 (0.41)	-0.887 (0.32)	-0.727 (0.26)
X * N interact	0.064 (0.57)	0.012 (0.16)	-0.123 (1.56)	-0.070 (0.80)
Population (N) [Millions]	0.022 (1.65)	0.015 (1.99)	-0.007 (0.86)	-0.003 (0.39)
No. Species Known		0.021 (6.10)	0.018 (4.95)	0.016 (4.30)
Arable Area [mill ha]			0.085 (1.84)	0.090 (2.93)
Population Density [no./ha]			0.101 (5.37)	0.067 (1.73)
Exports Rep. Skins [mill skins]			-0.995 (0.67)	-1.445 (1.49)
Closed Forest [mill ha]			-0.015 (2.04)	-0.005 (1.07)
Roundwood prod. [mill cub mt]			0.021 (1.17)	
Roundwood expt. [mill cub mt]				0.247 (1.48)
Sum Sq. Res.	1127	390.2	135.9	134.0
No. obs.	102	50	44	42
Adj. R squared	0.31	0.64	0.85	0.84

Data source: World Resources Institute.

TABLE 5.3 (continued)
SPECIES THREATENED: BIRDS

Dependent Variable: Number of Species Threatened

Intercept	17.77 (4.53)	-9.967 (1.60)	-1.657 (0.20)
GDP/Capita (Y) [1000 '87 US$]	1.259 (1.47)	2.612 (2.71)	0.384 (0.36)
Y^2	-0.067 (1.38)	-0.094 (1.89)	-0.008 (0.22)
Exports/GDP (X)	-23.59 (2.55)	-11.33 (1.59)	-11.52 (1.36)
X * N interact	0.591 (1.37)	0.027 (0.06)	0.653 (1.77)
Population (N) [Millions]	0.053 (1.19)	0.053 (1.63)	-0.042 (1.14)
No. Species Known		0.038 (4.01)	0.027 (3.19)
Arable Area [mill ha]			-0.130 (0.81)
No. Cattle [million]			0.786 (6.87)
No. Sheep [million]			0.168 (3.87)
No. Goats [million]			-0.982 (3.60)
Exports Live Parrots (mill birds)			-53.38 (2.75)
Closed Forest [mill ha]			-0.010 (0.50)
Roundwood expt. [mill cub mt]			-2.508 (2.86)
Sum Sq. Res.	21253	11194	3138
No. obs.	102	75	50
Adj. R squared	0.30	0.59	0.83

Data source: World Resources Institute.

TABLE 5.3 (continued)
SPECIES THREATENED: MAMMALS
Dependent Variable: Number of Species Threatened

Intercept	12.01 (4.78)	-12.78 (1.73)
GDP/Capita (Y) [1000 '87 US$]	3.135 (2.11)	2.861 (1.69)
Y^2	-0.183 (2.14)	-0.143 (1.69)
Exports/GDP (X)	-19.56 (2.36)	20.80 (1.82)
X * N interact	1.297 (2.33)	0.952 (2.28)
Population (N) [Millions]	-0.064 (1.69)	-0.228 (6.03)
No. Species Known		0.106 (4.10)
Arable Area [mill ha]		0.238 (1.18)
No. Cattle [million]		0.559 (4.79)
No. Sheep [million]		-0.129 (1.44)
No. Goats [million]		-1.048 (2.85)
Dummy for Mammal Expt.		-6.601 (3.32)
Closed Forest [mill ha]		-0.438 (4.32)
Roundwood prod. [mill cub mt]		0.481 (4.43)
Roundwood expt. [mill cub mt]		2.716 (2.33)
Sum Sq. Res.	6122	1261
No. obs.	64	36
Adj. R squared	0.34	0.74

Data source: World Resources Institute.

The number of reptile species threatened shows no particular pattern in connection with the economic measures included in Table 5.3. For the other groups of species an inverse u-shape with respect to income levels does tend to emerge, though in the case of freshwater fish this result is quite sensitive to inclusion of other country characteristics. The implication of the first estimate in each category, which includes no country characteristics, is that the threat to freshwater fish and amphibians achieves no meaningful turning point, but continues to rise with incomes albeit at a diminishing pace. For birds and mammals however, the threat indeed at first rises then declines beyond an income level of roughly 9,000 1987 US$ in both cases.

The pattern with respect to general export propensity is sensitive to inclusion of country characteristics in the case of freshwater fish and mammals. However, at least the basic economic model suggests a negative association between general export propensity and threat to each group of species, among countries with smaller populations. This pattern reverses, according to these estimates for countries with larger populations, except in the case of amphibians. The turning point in pattern with respect to export propensity is estimated to occur at around 30 million people in the case of freshwater fish, 40 million for reptiles and birds and 15 million for mammals. However, only in the case of mammals is there strong statistical confidence in both components of this export pattern.

In general the results in Table 5.3 indicate that it is the countries possessing a larger variety of species within each category which also threaten more species. This should, of course, be expected on a random basis. However, it does mean that the largest absolute global threat to species is in those countries with greatest biodiversity within the group (other things equal). For the most part, the foregoing observations about economic patterns are not affected with inclusion of this measure of the number of species (except in the case of freshwater fish and that threats to mammals are now clearly, positively associated with general export propensity). This robustness in the economic results is despite confinement of the extended results to a much smaller set of countries, owing to lack of data on known species for many countries.

In the case of freshwater fish the number of species threatened is sensitive to climatic zones. In particular the freshwater fish threatened are fewer in semi-arid areas and significantly greater in cold zones, relative to humid areas. The threat to fish is also greater in the tropics than in temperate areas, even given income levels. In fact, once these geographical components are included, the inverse u pattern with respect to income and the negative association with exports become much clearer. In the context of the other four major species groupings, the climatic zones matter far less according to our data, and these measures are therefore omitted from the results shown.

In the case of the (partially) land based animals, the association with agriculture is explored. Among amphibians, reptiles and (statistically weaker) mammals, more species are threatened where arable farming is more extensive. More birds and mammals are also found to be threatened where the numbers of cattle are greater, though this is not the case for amphibians and reptiles. More generally, the number of reptile species threatened proved larger where population pressure on the land is greatest, though no such clear pattern emerged for any of the other major groups.

Beyond the broad issue of whether more export oriented economies pose a greater threat to biodiversity, (perhaps though general orientation of production), there is an important issue with respect to trade in and hunting of specific species themselves. The data available to explore this latter topic are very limited in scope. Moreover, especially where trade is supposedly restricted, official data under-report actual trade. Nonetheless, Table 5.3 explores some of the reported data, such as they are. In no case is any positive association found. (Reported) exports of reptile skins, of live parrots, and of raw ivory, cat skins or live primates (the last three being represented by a dummy variable in the mammal regression) tend to occur from countries with smaller numbers of species threatened, if anything. Moreover, the average annual, freshwater catch of fish also has a weak negative association with the number of freshwater fish species threatened.

However, the effects of forestry upon land based species survival prove clearer. Among amphibians, reptiles and mammals, the number of species threatened is significantly less where the extent of surviving close forest is greatest. The corollary is that forest destruction may well pose a significant and major threat, though data on the change in number of species threatened are not available to test directly the association with rate of deforestation. Moreover, among amphibians, reptiles and mammals, the number of species threatened is positively associated with the rate of roundwood production and/or export (though in the first two cases these two measures are highly collinear and their separate effects cannot be distinguished). Among birds a similar effect from forest survival and wood production is not found, which is somewhat surprising given the consistency of the other results.

VI. Emissions and Waste

Some aspects of industrial and manufacturing emissions have already been examined in Sections II and III. In this final section some additional measures are examined. In particular, data on chloroflourocarbon (CFC) and methane (CH4) emissions from various anthropogenic activities, data on municipal waste in OECD countries, and on nuclear power are each analyzed in turn.

TABLE 6.1

CHLOROFLOUROCARBONS AND
METHANE FROM ANTHROPOGENIC SOURCES

Dependent Variable: Annual Emissions (1000 tonnes)

	CFC	CH4 Total	CH4 Solid Waste	CH4 Coal Mining	CH4 ONG	CH4 Rice	CH4 Live stock
Intercept	-2.052	109.5	27.12	318.3	194.2	-303.2	307.0
	(0.72)	(0.50)	(0.20)	(0.61)	(1.05)	(1.38)	(1.98)
GDP/Capita [1987US$]	0.002	0.238	0.139	0.070	0.023	-0.111	0.120
	(2.11)	(1.87)	(1.69)	(0.47)	(0.36)	(1.09)	(2.65)
Y^2/1000000	-0.045	-6.153	-2.261	2.230	0.163	-1.690	-5.946
	(0.76)	(1.04)	(0.53)	(0.18)	(0.06)	(0.22)	(2.18)
Exports/GDP	-18.01	-1553	-1095	-2650	-703.3	947.6	-749.0
	(1.91)	(1.38)	(1.58)	(1.37)	(0.92)	(1.65)	(1.92)
X * N inter.	0.977	-35.91	12.57	18.80	41.07	12.70	-52.58
	(2.62)	(0.65)	(0.51)	(0.77)	(1.06)	(0.22)	(3.30)
Population [Millions]	-0.016	56.58	6.194	1.887	-0.788	23.17	19.11
	(0.27)	(4.86)	(0.88)	(0.76)	(0.25)	(5.49)	(7.38)
F-statistic	6.39	60.70	6.44	2.36	1.65	78.40	65.64
No. obs.	64	98	98	30	43	72	97
R squared	0.30	0.75	0.22	0.19	0.07	0.84	0.77

Data source: World Resources Institute.

Chloroflourocarbon and Methane

Besides carbon dioxide, CFC and methane are the most important greenhouse gases. Data on their annual emissions as of 1989, reported by the World Resources Institute, are largely simulated from various underlying sources. Given this, there is little point in examining any association with the sources themselves and the analysis in Table 6.1 is therefore confined to our basic economic factors considered throughout this paper.

Both CFC and total methane emissions are estimated to rise initially with income per capita then to decline. However the latter effect is very weak statistically in both cases, and any implied turning point is projected to be somewhat beyond the income of the richest nations. In other words, both emissions rise with income level albeit at perhaps a diminishing rate.

CFC emissions tend to decline with export orientation up to a population level of around 18 million and to rise thereafter. Methane emissions, on the other hand, tend to decline with export propensity irrespective of population level (though the decline is not strong statistically).

The total methane emissions are the sum of simulated emissions from five sources and the same analysis is reported for each component separately in Table 6.1. The patterns vary. The inverse u pattern with respect to income levels emerges clearly only for methane emissions from domestic livestock and more weakly in the case of municipal solid waste. However, the negative association with export propensity generally holds up more or less strongly in the components. The only exception to the latter is in the case of wet rice cultivation where more export oriented countries tend to produce more wet rice. To a large extent this exception no doubt reflects the export orientation of the East Asian nations in particular, though it should be noted that in several of these countries rice production is heavily protected despite the more general outward orientation.

Municipal Waste

The World Resources Institute reproduces the OECD data on total municipal waste. The basis of these data differs by member country and the measures are therefore not strictly comparable. Nonetheless some patterns do emerge in Table 6.2.

Municipal waste per (urban) capita, even among these richer OECD nations, initially rises then declines with income per capita reaching a peak at around 13,000 1987 US$. On the other hand no stark pattern emerges with respect to export orientation among this set of countries, though there is a hint of a negative association.

TABLE 6.2

MUNICIPAL WASTE: OECD COUNTRIES

Dependent Variable: Annual Municipal Waste
Relative to Urban Population
(tonnes per person)

Intercept	0.277 (0.31)	5.966 (3.31)
GDP/Capita [1000 1987 US$] (Y)	0.309 (2.48)	0.234 (1.55)
Y^2	-0.012 (2.35)	-0.009 (1.28)
Exports/GDP (X)	0.300 (0.13)	-2.016 (1.12)
X * N interact	-0.059 (1.07)	-0.008 (0.14)
Population [Millions] (N)	0.010 (1.99)	0.006 (1.12)
Population Urban (%)		-0.053 (2.87)
Fraction Population Cities		-0.114 (1.69)
Sm.Sq.Res.	34.60	28.17
No. obs.	22	22
Adj. R squared	-0.10	-0.02

Data source: World Resources Institute.

Municipal waste per capita rises with the absolute size of population. The US is the most populous of the OECD nations and also generates the greatest municipal waste per capita. However, it is interesting to see that waste per capita tends to be negatively associated with urban and metropolitan concentration of the population, perhaps suggesting some scale economies in waste.

Nuclear Power

The last topic addressed in this paper is nuclear power. In a way it is different from many of the other measures considered. Nuclear power need not pose a threat if appropriately designed and operated. However, no indications of the potential for leaks are available, only some measures of the extent of power generated by nuclear means. Table 6.3 therefore examines the proportion of electric power generated from nuclear sources across countries.

TABLE 6.3

NUCLEAR POWER

Dependent Variable: Nuclear Production of Electricity
Relative to Total Electricity Production
(GWH/1000 tonnes oil equiv.)

Intercept	-0.172	-0.157	0.011
	(1.47)	(1.33)	(0.11)
GDP/Capita (Y)	0.213	0.196	0.214
[1000 1987 US$]	(2.39)	(2.12)	(2.31)
Y^2	-0.007	-0.006	-0.007
	(1.52)	(1.38)	(1.43)
Exports/GDP (X)	-0.826	-0.726	-0.880
	(2.61)	(2.18)	(2.96)
X * N interact	0.133	0.130	0.109
	(2.53)	(2.46)	(2.25)
Population (N)	-0.008	-0.009	-0.006
[Millions]	(2.30)	(2.41)	(1.66)
Energy Consumption		0.629	-0.513
[Bill tonnes coal equiv]		(1.78)	(0.70)
Electricity Generation			0.070
[Mill tonnes oil equiv]			(2.53)
Hydro Elec Installed			-0.112
[1000 MW]			(2.69)
Sm.Sq.Res.	95.37	93.77	83.33
No. obs.	76	75	75
Adj. R squared	0.33	0.33	0.39

Data source: World Bank Estimates.

Once again the now familiar inverse u pattern with respect to income per capita emerges with nuclear power relative to total power generation peaking at 15,200 1987 US$ per capita according to the first equation in Table 6.3. The proportion of power derived from nuclear sources initially declines with overall export propensity then rises among the more populous countries, reaching a turning point at 6.2 million people according to our first regression. Given these factors, it is the less populous countries which rely more heavily on nuclear power, though of course this is not necessarily heartening in terms of potential effect from fall out which readily transgresses international boundaries.

Since, for many nations, electricity is largely nontraded, power consumption and production are highly correlated. It is the high producers/consumers which tend to rely more heavily upon nuclear power, even given their income level. On the other hand, where hydro-electricity potential is exploited in installed capacity, reliance on nuclear power is significantly reduced. Presumably the implication is that if nations well endowed with potential hydro capacity were better able to exploit this and to export, world reliance on nuclear power could be reduced, though even hydro generation can have negative environmental consequences in its own right.

VII. Summing Up

Some lobbyists oppose freer global trade, because of its potential harm to the environment. Expanded trade in ivory presumably would pose an even greater threat to elephant herds, (though, as with narcotics, whether expanded legal trade and reduction in illegal activities would prove harmful is less clear). But opposition to expanded trade is frequently posed in more general form.

This paper has taken a wide range of international environmental indicators, such as they are, and asked whether those countries which are more outward oriented in exports show less respect for the environment. In the first two sections, it was also possible to ask whether greater outward orientation within any given country, on average, proves environmentally damaging with respect to certain industrial emissions. As one might expect the evidence is mixed. Nonetheless, it is probably fair to say that most of the estimates presented indicate less harm to the environment as export orientation increases, especially among smaller countries, though to this there are notable exceptions.

One might oppose trade liberalization on the grounds that it can raise incomes and hence indirectly impact the environment. In fact a remarkably consistent pattern emerges from the results presented here, of accelerating harm to the environment as income rises among lower income countries, then this effect either tapers off or reverses at higher income ranges. Again there are exceptions to this inverse u-shape pattern, but not so many. To argue that incomes of the poorer nations should be restrained to sustain the global environment poses a fundamental moral dilemma. It is therefore important to note that, in examining these data, no evidence at all is found that more rapid growth harms the environment in any way, given income levels. In other words, even if it proves true that the transition of the poorer nations into greater affluence damages the environment a more rapid transition does not seem to worsen the process.

Selected aspects of expanded trade probably would prove harmful to the environment. Several results in this paper point to the importance of the survival of forests. However, the results also suggest that although roundwood trade may be limiting the survival of wilderness there is no evidence in the data (given their severe limitations) that roundwood trade or production is resulting in permanent deforestation. Perhaps it is the change in the nature of the forest from roundwood production and trade which results in our finding that roundwood trade poses a direct threat to certain amphibians, reptiles and mammals.

Much remains to be done with these data. Several alternative specifications are reported in most contexts and reference is made to yet others, but further exploration of sensitivity of results to specification is required. The results presented here can all be viewed as essentially being in reduced form: environmental outcomes or correlates are related to endowments of the individual countries and to our economic measures, treating the latter as predetermined. More structural forms may warrant exploration, for some interdependence in our environmental indicators is probable. Pesticide use may well affect the number of bird species threatened, but this kind of interdependence remains to be explored. This may be important precisely because of the highly integrated and interdependent nature of ecosystems.