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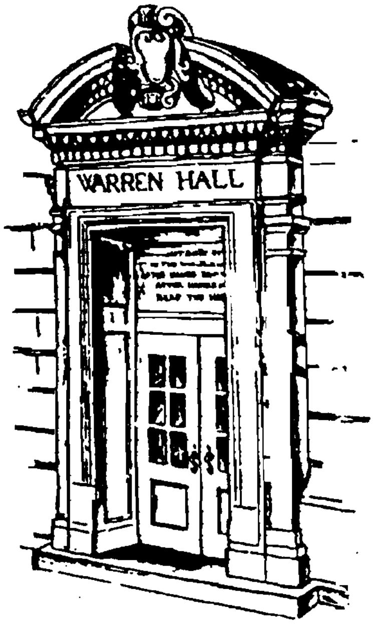

Working Paper

Department of Agricultural, Resource, and Managerial Economics
Cornell University, Ithaca, New York 14853-7801 USA

Economic Growth, Trade and the Environment: An Econometric Evaluation of the Environmental Kuznets Curve

Vivek Suri and Duane Chapman

ECONOMIC GROWTH, TRADE AND THE ENVIRONMENT: AN ECONOMETRIC EVALUATION OF THE ENVIRONMENTAL KUZNETS CURVE

Vivek Suri and Duane Chapman*

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*Department of Agricultural, Resource and Managerial Economics, Cornell University, Ithaca, NY. The authors wish to thank Bill Tomek for useful comments and suggestions.

Abstract:

The Environmental Kuznets Curve (EKC) hypothesis asserts that pollution follows an inverted-U path with respect to economic growth. The EKC has been explained in terms of structural changes in the composition of economic output and increased environmental regulation at higher income levels. Some authors have incorporated the impact of trade policy orientation on the EKC and they have generally concluded that openness is beneficial for the environment. However, the impact of the actual movement across countries of goods that embody pollution has not been considered. This paper attempts to quantify that effect. Following earlier studies, pooled cross-country and time-series data are employed to econometrically study the growth-environment-trade relationship. Commercial energy consumption per capita is used to represent stress on the environment. It is found that while both industrializing and industrialized countries have added to their energy requirements by exporting manufactured goods, the growth has been substantially higher in the former. On the other hand, countries have been able to reduce their energy requirements by importing manufactured goods and the magnitude of this effect is significantly larger in the industrialized countries. Exports of manufactured goods by industrializing countries has thus been an important factor in generating the upward sloping portion of the EKC and imports by industrialized ones have contributed to the downward slope.

Introduction

Recent empirical analyses of the relationship between economic growth and the environment have utilized the concept of an environmental transition hypothesis or the Environmental Kuznets Curve (EKC). The Environmental Kuznets Curve hypothesis asserts that pollution increases with economic growth up to a certain income level, after which it tends to decline. The inverted-U path for environmental quality has been explained in terms of structural changes in the composition of economic output and increased environmental regulation at higher income levels.

Some authors have incorporated factors such as international trade in their analysis of the growth-environment linkages. Their focus has been on the impact of trade policy orientation on the EKC and they have generally concluded that openness is beneficial for the environment. However, the impact of the actual movement between countries of goods that embody pollution has not been considered. Chapman (1991) raised this question while examining US trade in copper and automobiles but the nature of the study did not permit a detailed investigation of links with economic growth. This paper quantifies the interaction of trade in manufactured goods with the growth-environmental quality relationship.

Following earlier studies, pooled cross-country and time-series data are employed to study econometrically the growth-environment relationship. Commercial energy consumption per capita is used to represent stress on the environment. The ratios of imports and exports of all manufactured goods to total domestic production of manufactures capture the impact of a country's involvement in international trade on pollutant generation. Real GDP per capita measures economic growth, while structural change is represented by the share of manufacturing in GDP.

It is found that in an era of expanding world trade, while both industrializing and industrialized countries have added to their energy requirements by exporting manufactured goods, the growth has been substantially higher in the former. On the other hand, countries have been able to reduce their energy requirements by importing manufactured goods and the magnitude of this effect is significantly larger in the industrialized countries. Exports of manufactured goods by industrializing countries has thus been an important factor in generating the upward sloping portion of the EKC and imports by industrialized ones have contributed to the downward slope.

The paper is organized into 3 major sections. Section I describes the model that has been used in the past to analyze the growth-environment relationship and the modifications that we introduce. It is divided into sub-sections that discuss the dependent and independent variables in detail. Section II presents the results from the econometric estimation. Section III provides some conclusions.

I. THE MODEL

The model that is frequently used to study the relationship between economic growth and pollution using pooled cross-country and time-series data is a version the following reduced form (see Grossman and Krueger (1991 and 1995), Holtz-Eakin and Seldon (1995), Seldon and Song (1994), Shafik and Bandyopadhyay (1992)):

$$Y_{it} = \alpha_i + \gamma_t + \beta_1 X_{it} + \beta_2 X_{it}^2 + \beta_3 X_{it}^3 + \beta_k Z_{kit} + e_{it}$$

where,

i = 1,...N, countries

t = 1,...T, years

Y_{it} = environmental stress variable

α_i = country specific intercept

γ_t = time specific intercept

X_{it} = real GDP per capita

Z_{kit} = other variables that impact environmental quality

e_{it} = an error term

Examples of variables included in Z_k are indicators of openness to trade and population density. The GDP-cubed term is not always included in the model.

I (a). The Dependent Variable

The definition of Y_{it}, the environmental impact variable, differs among the studies. Some analysts have used ambient concentrations of pollutants to represent environmental quality. Typical examples of this measure include the amount of SO_2 or suspended particulates (in micrograms) per cubic meter of air in a city, the water quality of rivers also measured by contaminants by weight per unit volume, etc. Others have taken the *total* generation of a certain pollutant in a country and divided it by the country's population to represent environmental degradation. Examples of this variable include per capita emissions of pollutants such as CO_2, SO_2 or NO_x expressed in units of carbon, sulfur or nitrogen respectively. The distinction between the two types of measures is important since declining ambient concentration in a city need not imply that the overall pollution burden for the country is falling.

The dependent variable that we employ is the consumption of commercial energy per capita, expressed in terms of oil equivalents. Since commercial energy includes all the energy derived from fossil fuels, it can serve as a good measure of the overall pollution burden associated with them. In addition, since nuclear energy is also included in commercial energy, the pollutants generated from this form are also accounted for. It is important to include nuclear energy because a number of countries have been able to reduce fossil fuel related pollutants by increasing their nuclear capacity.

I (b). Explanatory Variables

i) GDP

The explanatory variables common to all econometric studies of the growth-environmental relationship are real per capita GDP and its square, GDPSQ. The GDP variable represents the scale of economic activity or economic growth or income. Other things remaining equal the larger the scale of economic activity the higher is the generation of pollutants. The GDPSQ term, on the other hand, represents some of the things that do not remain the same as GDP grows. These include structural transformation in the composition of GDP and increasing environmental awareness and regulation. The structural composition of GDP first moves in favor of the pollution intensive[1] industrial sector while the share of agriculture declines. At higher stages of development the share of industry begins to fall while that of the non-pollution-intensive service sector rises (Syrquin and Chenery, 1988).

Thus, at high income levels, the composition of GDP pushes the economy towards a lower overall energy intensity (i.e. a lower energy to GDP ratio). This has a dampening effect on energy growth in per capita terms. In the absence of a cubic term, the GDPSQ term is expected to have a negative sign.

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[1] Since high pollution intensity also generally implies high energy intensity, the two terms are used interchangeably.

In models that include GDP-cubed the inverted-U shape can be generated by different combinations of signs and magnitudes of the coefficients on the GDP terms. In some models with the cubic term, the estimated relationship turns up again at very high income levels, a feature which does not have a clear economic interpretation.

As for environmental regulations, while they have tended to reduce pollutants per unit of energy they have not had a sizable impact on energy demand itself. The energy conservation efforts that have been undertaken have largely been responses to higher energy prices and not to environmental controls. Therefore, in the case of energy (or CO_2) GDPSQ does not pick up the effect of regulation as it may do for some other pollutants.

The per capita GDP level at which the turning point for pollution occurs differs between pollutants and their different measures (per capita or concentrations). Seldon and Song (1994) point out that ambient concentrations in urban areas will turn down at lower levels of per capita income than will aggregate emissions per capita. This is because air pollution in cities poses more immediate health risks than in rural areas, improvements in urban air quality can be achieved at relatively lower costs than aggregate emissions, rising land rents push industries out of urban areas and residents of cities have incomes that are higher than the national average which gives them more political clout.

For ambient concentrations of SO_2, Grossman and Krueger (GK) estimate the turning point to lie between $4000-$5000 per capita (in 1985 PPP US$) while Shafik and Bandyopadhyay (SB) estimate it at $3,670. The GK (1991) curve from their cubic equations is reproduced in Figure 1. Note that for both measures of SO_2 concentration the estimated relationship turns back up again at $ 14000, a finding that is difficult to explain. In terms of its per capita burden, SO_2 is found to peak at about $8,000-$10,000 (Seldon and Song, 1994).

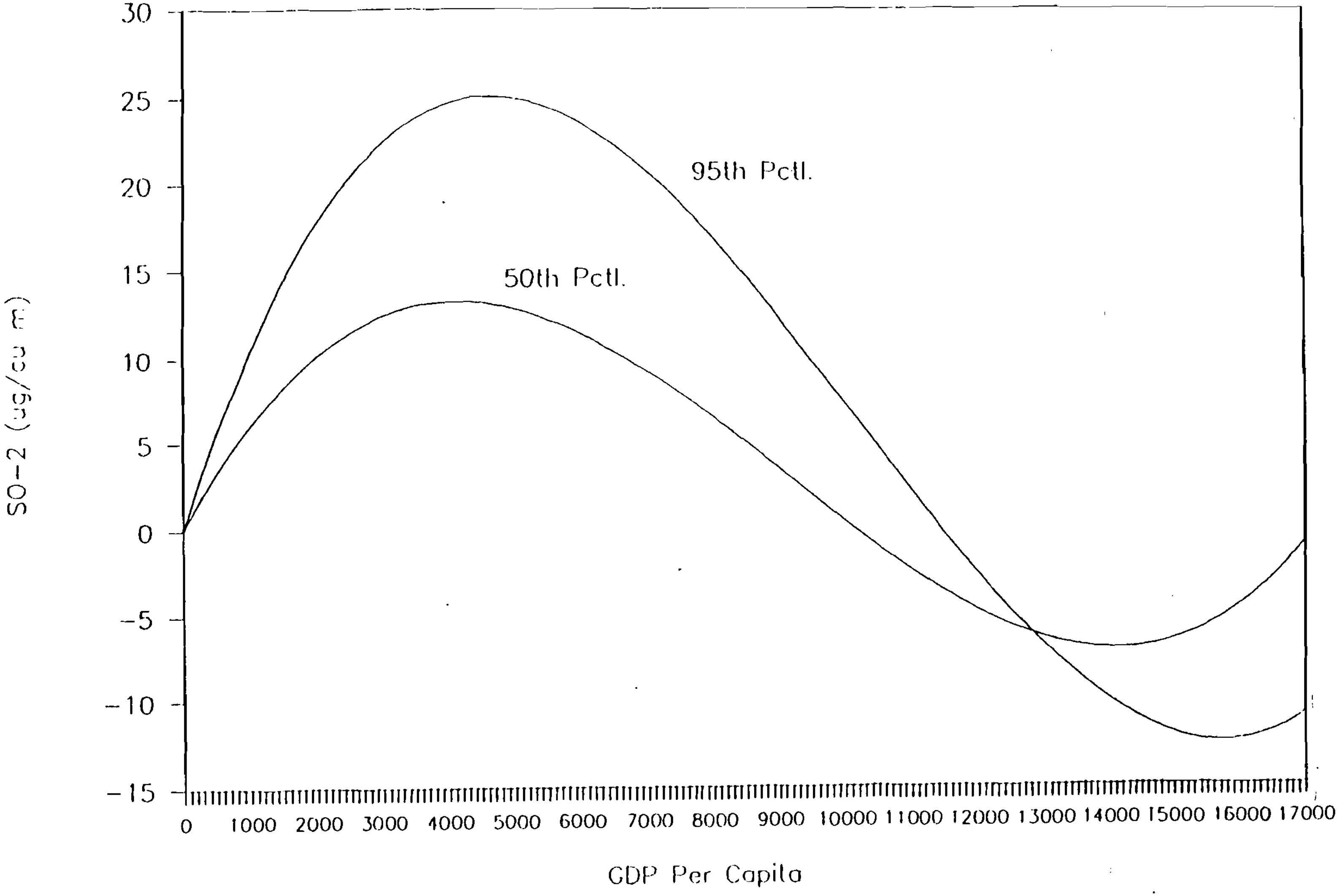
Concentration of Suspended Particulate Matter peaks at $3,280 while its per capita load turns down between $8000-$10,000. Emissions of CO_2 in per capita terms are predicted to turn down at very high levels of income which lie well above the sample range. Within the sample a declining, though positive, marginal propensity to emit is observed (Holtz-Eakin and Seldon, 1995). In the case of the log-quadratic specifications of their models Holtz-Eakin and Seldon and SB estimate turning points for CO_2 at $8 million and $7 million respectively.

ii) Trade Variables

Most authors have also included other variables that influence the growth-environment relationship. One such influence is through a country's participation in international trade. Grossman and Krueger (1991) and Shafik and Bandyopadhyay use the trade intensity variable, defined

Figure 1

SO_2 vs GDP per capita



Source: Grossman and Krueger (1991).

as the ratio of imports plus exports to GDP, to capture the impact of international trade. They hypothesize that the more open a country's trade regime (i.e. a higher trade intensity) the cleaner are the production processes it employs. While GK conjecture that this might be because environmental regulations tend to a least common denominator, SB provide other explanations as well. They feel that "openness and competition will tend to increase investment in new technology which embodies cleaner processes to meet the higher environmental standards of technology exporting countries." Also, countries that follow protectionist policies often protect capital-intensive polluting industries. Another variable used to study the impact of trade orientation is Dollar's Index of openness. Broadly, this is a measure of price level distortion in an economy. The higher its value the more open the trade regime. This measure is used by SB and Lucas et. al (1992).

The results that these authors obtain are mixed. Their expectations are borne out only in the case of some measures of environmental degradation. For instance, GK find only SO_2 to have a significant and negative association with trade intensity. For suspended particles the coefficient has the wrong, though statistically insignificant, sign. SB's results are sensitive to the functional form and the measure of openness employed. The results for SO_2 with the trade intensity variable were good, but when the quadratic specification was combined with Dollar's Index the coefficient had a significantly incorrect sign.

The common feature of these earlier studies has been that they have analyzed the impact of *trade policy orientation* on pollutant generation. This, of course, is very relevant and their results do seem to be logical. However, another channel through which trade can affect the relationship between growth and pollution, is through the *actual flow of goods between countries.* This important channel is noted by both GK (1995) and Seldon and Song, but is not incorporated explicitly.

Trade entails the movement of goods produced in one country for consumption (or further processing) in another. This implies that the pollution generated in the production of these goods is related to consumption in another country. GK (1995, p. 372) note that the downward sloping portion of the Environmental Kuznets Curve could arise "because as countries develop they may cease to produce certain pollution intensive goods and begin instead to import these from other countries with less restrictive environmental controls." They rely on a study by Tobey (1990) to conclude that the magnitude of this impact is small. In their own work (GK, 1991, p. 35) they in fact suggested that, in the context of NAFTA, it was possible for the reverse effect to occur, "On the global level, a net benefit may derive from the movement of dirtier economic activities to the more highly regulated production environments."

Lucas et. al., on the other hand, present evidence which is consistent with the hypothesis that stricter environmental regulation in OECD countries has led to a locational displacement of dirty industries towards poorer countries. Further, Low and Yeats (1992) point out that pollution intensive industries account for a growing share of exports of some developing countries, while in the case of industrialized countries' exports, the share of dirty industries has declined.

We, however, feel that it is not enough to look only at trade in pollution intensive goods, but at a much wider range of manufactured goods in order to capture the impact of trade on pollutant generation. This is because there are a number of manufactured goods whose production releases only a small amount of pollutants directly, but since pollution intensive inputs are used in the production chain, the indirect effect on pollution can be sizable. This point is brought forth strongly in Wyckoff and Roop (1994) and OTA (1990).

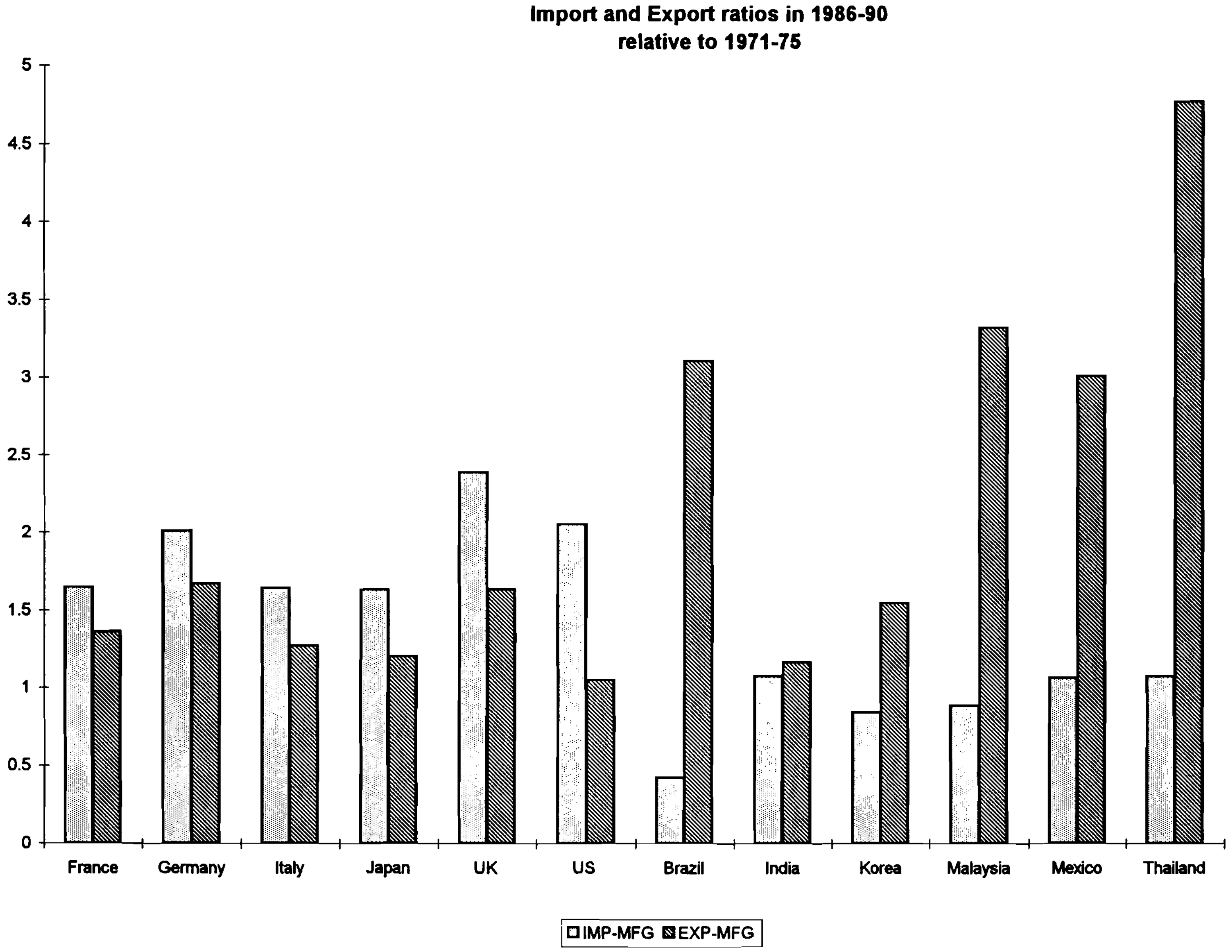
An example is trade in motor vehicles. While the actual manufacturing and assembling processes do not require large amounts of energy, they use a number of inputs like steel and rubber that are highly energy (and pollution) intensive. Thus trade in motor vehicles would produce a small amount of pollution directly but a significant amount indirectly. OTA (1990) estimated that all the cars produced in the US required only 23 quads of energy directly but the direct plus indirect energy content was nearly six times as large. A similar story holds for electrical and non-electrical machinery and even some light manufacturing. Wyckoff and Roop estimated the carbon embodied in the manufacturing imports of five major OECD countries. They found that the ratio of carbon embodied in imports to total carbon emissions in these countries was significant, ranging from just under 10% in Japan and the US to over 40% in France. The ratio of carbon embodied in imports to industrial carbon emissions would certainly be much higher. Importantly, they found that almost half of this carbon was embodied in the non-energy intensive products. This underscores the point made above that in order to assess the impact of trade on pollution a much wider class of manufactured goods needs to be considered.

In order to capture this aspect of the role of international trade, we include additional explanatory variables in the regression equation.

a) Import-Manufacturing ratio

The first variable we include is the ratio of imports of *all* manufactured goods (both energy and non-energy intensive) to domestic production of all manufactures (M-MFG). In the 1971-1990 period this ratio increased in nearly all industrialized countries. In most developing countries M-MFG either remained steady or declined (Figure 2). In countries where it rose the rate was much lower than

Figure 2


Import and Export ratios in 1986-90
relative to 1971-75
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
France
Germany
Italy
Japan
UK
US
Brazil
India
Korea
Malaysia
Mexico
Thailand
□ IMP-MFG ▨ EXP-MFG

in the industrialized nations. To some extent this reflects import substituting industrialization.

A rise in the M-MFG ratio can have opposite effects on energy requirements. On the one hand, imports could substitute some manufactured goods that were earlier produced domestically. This would include those industries that have developed overseas in response to stricter environmental standards in the home country. Also included here would be industries that have been attracted to other countries with lower labor and raw material costs. Another case would be the introduction of a new production process that replaces domestically produced inputs with imported ones. In any of these cases it is not critical to our analysis as to whether it was the migration of industries or some other factor that caused the import-manufacturing ratio to increase. For our purpose the important fact is that, ceteris paribus, imports of these commodities, by replacing domestic production, would reduce the energy requirements of the country.

On the other hand, imports of certain types of machinery could lead to an increase in energy requirements. This would happen in the case of capital goods which are used to produce goods not hitherto manufactured domestically and the energy-intensity of the new goods is higher than the average for other domestic production. The net effect of a rise in the import to manufacturing ratio could thus be positive or negative. It is, however, likely that countries that are industrializing and hence expanding their production base, would be the ones that have larger imports of such capital goods than the industrialized ones. Therefore, in these low and middle income countries the positive effect on energy requirements can be quite large. It is in the high income countries that imports would have a strong substitution effect on energy demand. In order to test whether this is true we also include a term that tests the interaction of income with the M-MFG ratio.

b) Export-Manufacturing ratio

Two other variables that we include in the analysis are the ratios of exports of manufactured goods to domestic manufacturing production (X-MFG) and the ratio of total manufacturing value added to GDP (MFG-GDP). Both these variables are similar in that they reflect the level of industrial maturity and increases in them move a country's economy towards a more energy intensive production mix. There are, however, important differences in what the variables capture as we note below.

The increase in energy requirements as a result of a rising X-MFG ratio represents the impact of the country's participation in international trade. The embodied energy that is required to produce exports is in a sense "consumed" in another country. In an era of expanding world trade, exports have been the most dynamic part of the manufacturing sector and as a consequence the X-MFG ratio has been rising in nearly all the countries in our sample. The rate of growth though has been much higher in the industrializing countries (Figure 2). This growth represents the exploitation of overseas markets by these countries in their drive towards industrial maturity. In general, industrializing countries begin by exporting light manufactures and then move on to the heavier variety. A very large part of their markets are located in the high income countries. Some of these markets increased because the industrialized countries reduced or stopped their production of certain goods which became available at lower prices from the developing countries.

iii) Structural Change Variable

The share of total manufacturing in GDP (MFG-GDP) includes production of manufactures for the domestic market in addition to production for export. It is a measure of the broad structural transformation that an economy goes through as it develops. The rapidly industrializing countries have witnessed a sharp rise in the share of the manufacturing sector. In the industrialized world this share is either growing slowly, or has stabilized or is declining. In these countries the share of the non-energy-intensive service sector has been on the rise. This implies that while the overall structural transformation of the economy is leading the industrializing countries towards greater energy intensity, the richer nations are generally moving in the opposite direction. It may be noted that a rise in the MFG-GDP ratio captures more than just the greater amount of energy required to produce industrial goods. Importantly, it also reflects some of the correlates of industrialization like urbanization and growing transportation needs, which tend to increase the energy requirements of a country.

iv) Country and Time Effects ("Fixed Effects")

Apart from the growth, trade and structural change variables, there are a number of country specific factors that influence energy requirements. Examples of such factors are resource endowments, climate, geographical location and culture. These aspects of a country do not change over time. Following earlier studies we control for these factors by including country specific dummy variables. In addition to these we also include a dummy variable for each year. This allows us to control for factors that evolve over time and impact all countries, for example, world energy prices and technological developments.

III. ESTIMATION RESULTS

The data set we employ consists of observations on 33 countries over a 20 or 21 year period beginning in 1971 and ending in 1990 or 1991 (for details of the data set please see the Appendix). A number of different, though related, fixed effects models were estimated. Each model includes 'N' country dummies and 'T' time dummies. In all the models we detected first order serial correlation in the residuals. In order to correct for this we specified an error structure of the following form

$$e_{it} = \rho e_{i,t-1} + v_{it} \qquad |\rho| < 1$$

$$v_{it} \sim IID(0, \sigma_v^2)$$

In this specification every country is assumed to have the same autocorrelation parameter (ρ). The results that we present here are the feasible GLS (FGLS) estimates obtained after correcting for serial correlation[2]. Since all the variables were used in log terms, the estimated coefficients are the relevant elasticities.

Model 1 is a version of the growth environment relationship frequently encountered in the literature. The variable representing environmental stress is regressed on the logarithm of GDP and its square. Our results are consistent with the earlier studies in that GDP has a positive sign and the GDPSQ term has a negative sign. This means that the elasticity of energy with respect to GDP falls as GDP rises. The turning point of this inverted-U curve (i.e. the point where elasticity falls to zero) occurs at a GDP of US $ 54,598 which is nearly 3 times the highest level of GDP in our sample.

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[2] The AUTOREG procedure of SAS was used to correct for serial correlation. In order to create a break between the last observation for country 'n' and the first observation for country 'n+1' a fake (missing) observation was inserted.

TABLE 1

Dependent Variable: Log Energy Per Capita

MODEL	1	2(a)	2(b)
GDP	1.192	1.107	0.781
	(21.297)	(13.461)	(15.330)
GDPSQ	-0.149	-0.112	
	(-9.109)	(-6.135)	
M-MFG		-0.026	-0.038
		(-1.537)	(-2.213)
X-MFG		0.087	0.095
		(6.306)	(6.708)
MFG-GDP		0.068	0.199
		(1.301)	(3.965)
R-sqr	0.9846	0.9873	0.9842

Notes:

1) All variables are in logs.

2) t-values in parentheses.

3) All models include country-specific and time-specific dummies (fixed effects).

4) The estimates are FGLS estimates obtained after correcting for first order serial correlation.

As explained earlier the GDPSQ term in Model 1 is a catch-all term. In the other models that we present we add some variables to Model 1 in the hope of identifying some of the influences that might be captured by GDPSQ. Two versions of each of the models are presented. Version (a) includes the GDPSQ term in addition to the new variables while Version (b) excludes it from the regression.

Model 2 adds the trade variables (M-MFG and X-MFG) and MFG-GDP, the variable representing overall structural change. In both 2(a) and 2(b) all signs are as expected and the t-values are sufficiently large. Note that the inclusion of the additional variables in model 2(a) reduces the magnitudes of the coefficient and t-ratio for GDPSQ. In model 2(b) the exclusion of GDPSQ leads to larger coefficients for the M-MFG and MFG-GDP terms. The t-values are also higher. This finding is important because the new variables were introduced for the purpose of capturing some of the effects that were proxied by GDPSQ. The results indicate that we have been successful to that extent.

In Models 3 and 4 we try to test whether the impact of imports of manufactured goods on energy consumption is related to a country's income level. In Model 3 we include an interaction between GDP and the ratio of manufactured goods imports to GDP. It was our hypothesis that the substitution effect of imports is likely to be larger in high income countries than in the low and middle income ones. Thus we would expect the sign on the interaction term to be negative. This is indeed what we find in both 3(a) and 3(b). In 3(a), however, the t-value is lower. This is probably because the inclusion of the interaction term increases the collinearity in the data set and it becomes difficult to disentangle the effects of the individual regressors with precision.

In Model 4 the countries are divided into two groups, low and middle income countries and high income countries. HIE is a zero-one dummy variable representing high income countries. This variable is interacted with the import variable to allow the two groups of countries to have different slopes with respect to imports. The partitioning of the sample into low-middle income countries and high income countries follows quite naturally from the discussion in the previous section. Coincidentally, it also allows us to avoid some of the collinearity problems of the earlier interaction variable. The results are better in that in addition to having the expected signs the t-value for the HIE interaction is quite high.

In both versions of Models 3 and 4 the coefficient on M-MFG is not significantly different from zero. The likely explanation for this is that the positive and negative impacts of imports in the industrializing countries (alluded to above) tend to cancel each other out.

Models 1-4 can be compared at two levels. First, we can compare the versions (a) and (b) of a given model. Second, we can compare across the models. Comparing

TABLE 2

Dependent Variable: Log Energy Per Capita

MODEL	3(a)	3(b)
GDP	1.080	0.789
	(15.118)	(15.599)
GDPSQ	-0.102	
	(-5.311)	
M-MFG	-0.000	0.009
	(-0.003)	(0.416)
M-MFG*GDP	-0.026	-0.046
	(-1.793)	(-3.219)
X-MFG	0.086	0.091
	(6.200)	(6.467)
MFG-GDP	0.059	0.161
	(1.127)	(3.145)
R-sqr	0.9873	0.9846

Notes:

1) All variables are in logs.

2) t-values in parentheses.

3) All models include country-specific and time-specific dummies (fixed effects).

4) The estimates are FGLS estimates obtained after correcting for first order serial correlation.

TABLE 3

Dependent Variable: Log Energy Per Capita

MODEL	**4(a)**	**4(b)**
GDP	1.053	0.765
	(14.682)	(15.316)
GDPSQ	-0.098	
	(-5.231)	
M-MFG	-0.002	-0.005
	(-0.125)	(-0.275)
M-MFG*HIE	-0.128	-0.168
	(-3.475)	(-4.588)
X-MFG	0.084	0.090
	(6.111)	(6.403)
MFG-GDP	0.078	0.193
	(1.513)	(3.957)
R-sqr	0.9884	0.9861

Notes:

1) All variables are in logs.

2) t-values in parentheses.

3) All models include country-specific and time-specific dummies (fixed effects).

4) The estimates are FGLS estimates obtained after correcting for first order serial correlation.

Versions (a) and (b) for any model we find that dropping GDPSQ raises the coefficient and t-values of the other regressors. The largest increase is for MFG-GDP followed by the import variables. The MFG-GDP coefficient increases nearly two-and-a-half to three times. The increase in the import-GDP interaction variable is 75 per cent in Model 4 and 30 per cent in Model 4. The impact of dropping GDPSQ on X-MFG is relatively much smaller. These changes in the coefficient and t-values suggest that the two important effects on energy requirements through structural change and imports were being captured by GDPSQ.

A similar observation can be made by comparing Model 1 with version (a) of the other three. We note that the coefficient of GDPSQ and its t-value are smaller in the latter three models. The t-values for GDPSQ in Model 3 and 4 are nearly half of those in Model 1, while the coefficient is 33 per cent smaller. Since these models identify the influences captured in the catch-all term, they are preferable to Model 1.

Contrasting Model 2 on the one hand with either Model 3 or 4 on the other, reveals that it is important to distinguish the impact that imports of manufactured goods have on energy requirements at different income levels. For this reason Models 3 and 4 are preferable to Model 2 which does not make this distinction. Choosing between Models 3 and 4 is more difficult. Model 3 has the virtue of having a continuous interaction. However, since our sample can be logically divided into two categories on the basis of income and industrialization levels, adopting a discontinuous interaction is not problematic. Further, given that we want to distinguish the differential impacts of imports in low-middle income countries and high income countries, rather than at every income level, we tend to favor Model 4.

III. CONCLUSIONS

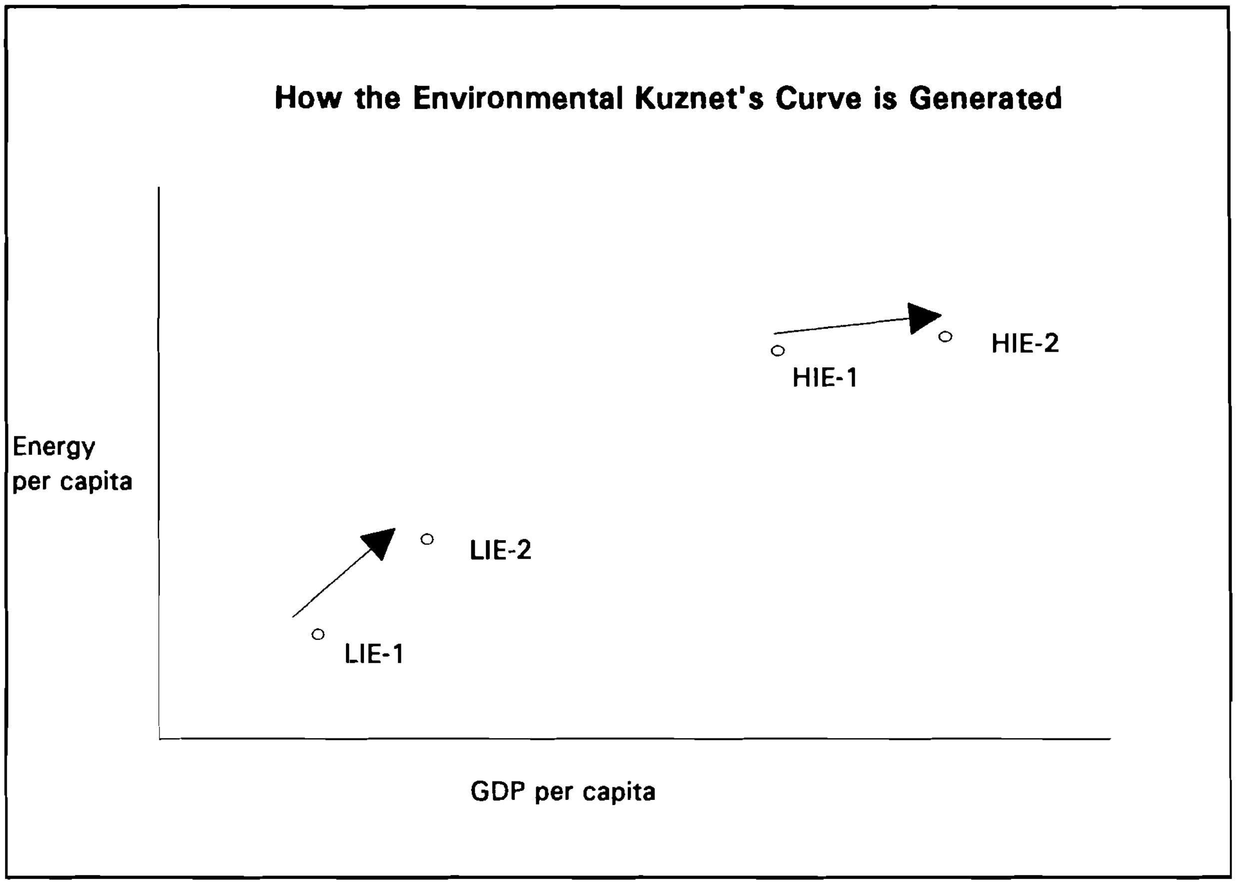
In this paper we have quantified the effect that growth, structural change and international trade have on environmental stress measured in terms of commercial energy requirements. Whereas in some earlier studies the impacts of structural change and trade were captured in GDPSQ, we model them explicitly. Our results suggest that after controlling for scale and structural change effects, international trade has played an important role in the generation of pollutants within countries. Countries that have exported increasing proportions of their manufacturing production have had their energy requirements positively impacted. Since the X-MFG ratio has increased at substantially higher rates in the industrializing countries, the magnitude of this effect is much larger for them than for the industrialized ones. On the other hand, the industrialized countries have been able to reduce their energy requirements by increasing imports of manufactured goods relative to domestic production. A 10 per cent rise in the M-MFG ratio reduces energy requirements by 1.3-1.7

per cent. Imports of manufactured goods do not seem to have had a similar effect on industrializing countries.

What implications do these results have for the EKC hypothesis? First, note that in the case of energy consumption per capita the turning point has not yet been reached by any country. However, in the developed countries the percentage increase in energy requirements associated with a percentage increase in GDP is declining, i.e., they have reached the flatter part of the curve (Figure 3). Our analysis indicates that, apart from structural change, imports of manufactured goods by these countries have also played a crucial role in this decline.

The question then is can the countries that are on the steep segment of the upward slope achieve similar reductions in their energy elasticities? Undoubtedly, some decreases in energy elasticities will occur as the composition of GDP moves in favor of the services sector. In order to achieve greater reductions, can the industrializing countries find other countries to import from and importantly, given that their economic progress is based on exports will they be willing to do so? As far as the first question is concerned, the world would eventually exhaust the set of countries from which to import. The second question raises further issues with respect to development policies. The answer to that will depend on the role accorded to international trade in future development plans.

Figure 3



LIE: Low Income Economy
HIE: High Income Economy
1 and 2 refer to two different time periods.

Source: Adapted from Agras (1995).

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Tobey, James A., "The effects of Domestic Environmental Policies on World Trade: An Empirical Test," *Kyklos*, 43, 191-209, 1990.

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Appendix: Data Sources

Energy Data: Consumption of Primary Commercial Energy per capita in tons of oil equivalents was obtained from the following publications of the International Energy Agency:

Energy Balances of OECD Countries 1970/85, International Energy Agency, Paris, 1987.
Energy Balances of OECD Countries 1990-91, International Energy Agency, Paris, 1992.
Energy Balances of Non-OECD Countries 1991-1992, International Energy Agency, Paris, 1993.

GDP: The RGDPCH variable from the Penn World Tables 5.6 was used. This is a real GDP series expressed in 1985 Purchasing Power Parity (PPP) Dollars. RGDPCH is used by nearly all other studies of the EKC. The Penn World tables are available on the NBER FTP site located at Harvard University. A description of these tables appears in Summers and Heston (1991).

Summers, R. and A. Heston, "The Penn World Table (mark V): An Expanded Set of International Comparisons, 1950-1988," *Quarterly Journal of Economics* 106(2), 327-368, 1991.

Manufacturing Share in GDP: Constant price data on manufacturing value added (MVA) were divided by constant price GDP data. Industrial Value Added was used for countries that did not report MVA. All these series were taken from World Tables 1993, available electronically on the STARS data retrieval system of the World Bank. The countries for which complete series were not available, World Tables data were supplemented by data from the National Accounts Statistics published by the United Nations. For U.K. only current price data were available for MVA.

World Bank, *World Tables 1993*, Johns Hopkins University Press, Baltimore.

United Nations, *National Accounts Statistics: Main Aggregates and Detailed Tables*, United Nations, New York, *Various Issues*.

Trade Data: Data on exports and imports of manufactured goods in current US $ are also taken from World Tables 1993. In order to bring the data to constant prices, unit value indicies for manufactured goods (in US $) from the UN (1991 and 1992) were used. For developed countries separate deflators for exports were available for each country. For developing countries individual deflators were not available, and only a common deflator was reported. In the case of imports of manufactured goods, individual country deflators were not provided for developing as well as developed countries. The average export price index for manufactured goods for developed countries was used to deflate the imports of all countries.

United Nations, *International Trade Statistics Yearbook*, United Nations, New York, 1991 and 1992.

Countries: Argentina, Australia, Austria, Brazil, Bangladesh, Canada, Chile, China, Denmark, Finland, France, Germany (West), Greece, Hong Kong, Iceland, India, Indonesia, Japan, Kenya, Korea (South), Malaysia, Mexico, Netherlands, Norway, Pakistan, Portugal, Spain, Sweden, Thailand, Turkey, United Kingdom, United States and Zimbabwe.

OTHER A.R.M.E. WORKING PAPERS

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