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Interrelationships and Causal Linkages Between Socioeconomic and Environmental Factors

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Abstract

The purpose of this study was to examine interrelationship and causal linkages between socioeconomic and environmental variables in OECD countries. To aid this study, a LISREL modelling tool was implemented.

The findings of the study indicated that gross public debt increases with deterioration in air quality in North America, Asia and the Pacific, Central, Eastern and Atlantic regions of Western Europe. Energy consumption contributes to deterioration of air quality in all regions. Economic growth, measured by growth in GDP, accelerates deterioration of air quality in all regions except in Southern and Eastern regions of Western Europe. Increases in energy consumption and economic growth contribute to declines in gross public debt in most OECD countries.

Spending for environmental protection contributes to reduced emission of CO_2 in all regions of Europe except Asia/Pacific and North America. Expenditure for environmental protection causes increases in public debt in all regions. However, environmental expenditure exerts positive impact on economic growth in Asia/Pacific and Central Europe. Spending in environmental protection is associated with reduction in emissions of most pollutants except in North America and Asia/Pacific and Southern regions of Western Europe.

[1] The views expressed in this paper are those of the authors not Environment Canada.

The findings also indicated that in regions where emission of SO_2 is the greatest, harvesting of forests increased while fish catches declined. Emission of NO_x is associated with increases in agricultural production in most regions, except in Southern and Atlantic regions of Western Europe and North America. Emission of VOCs contributed to reduction in agricultural production in most regions except in Central regions of Western Europe. In summary, economic growth tends to significantly contribute to energy consumption and deterioration of air quality. However, the later can be improved through aggressive spending in environmental protection. Therefore, it is imperative to identify a strategy that would balance economic growth and energy consumption with improved environmental quality.

Introduction

Environment includes both physical (e.g., land) and nonphysical (e.g., institutions) resources. It is the improvement or change in these resources that defines development. Therefore, environment and development are intrinsically connected. It is impossible to talk about development without discussing the constituents of environment.

The intricate relationship between environment and economics calls for their integration as a means to achieve environmentally sound and sustainable development. The last few decades have witnessed the introduction of environmental policies designed to work together with economic policies. There has been moderate progress toward harmonizing environmental and development policies. Environmental policies have largely been viewed as appendages, in which remedial and/or preventive action is taken once economic priorities are implemented, and environmental degradation has taken place. By contrast, sustainable development requires the integration of environment and development at the outset of the decision-making process, so as to align economic, energy, transportation, forestry, fisheries, and other strategies with environmental goals. Indeed, one of the key issues that emerged from the Rio Declaration on Environment and Development and Agenda 21 is that environmental considerations have to be integrated into development planning to attain sustainable development.

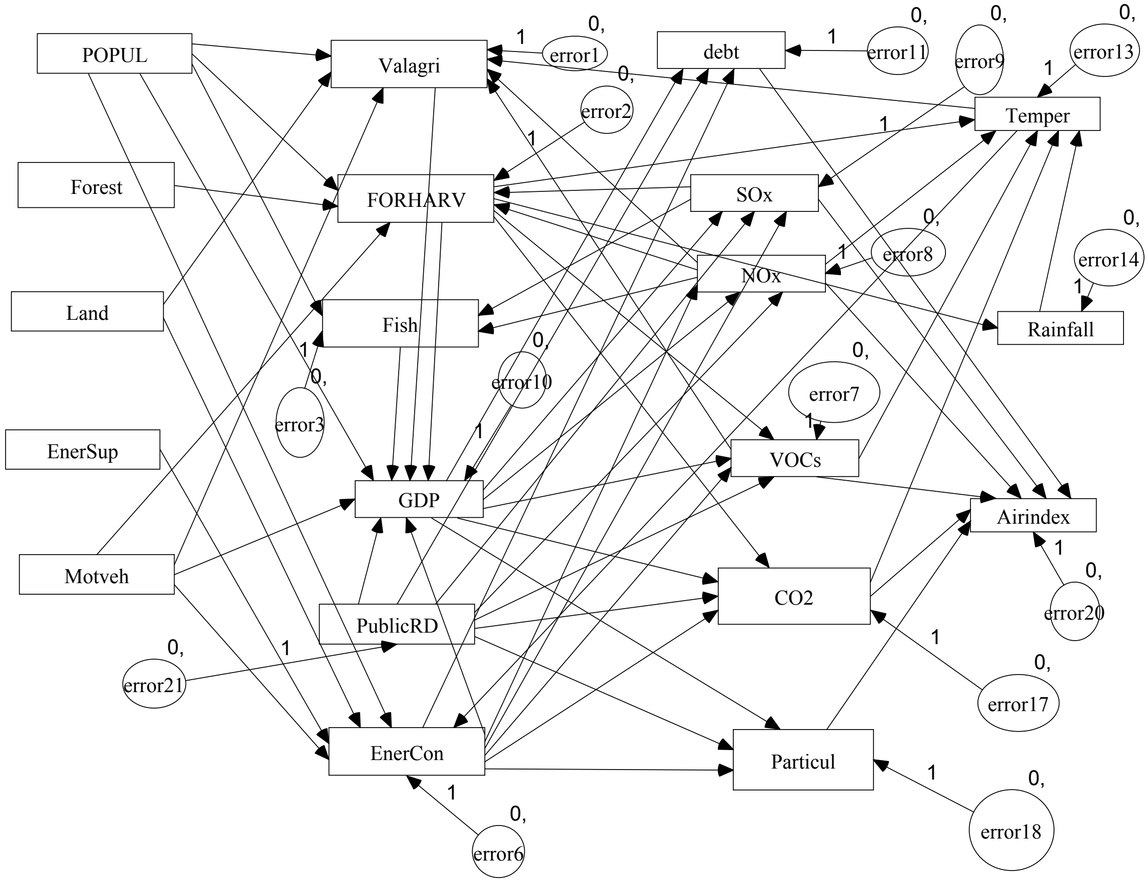
Attainment of sustainability, equity and stability, would require strengthening an understanding of the interacting environmental and socioeconomic variables, among other things. The basic principle for examining the integration of the environment with the economy is the recognition that all economic activity requires materials and energy drawn directly and indirectly from the environment and, that ultimately, these materials and energy are returned to the environment as waste products. Not only is the economy a subsystem of the ecosphere; it is also a subsystem of the larger set of activities that make up social life. It is within this dependent relationship (i.e., of the economy operating within the environment) that interrelationship between socioeconomic and environmental variables examined.

Recent developments in the study of the linkages between economy and environment have taken the form of integrated assessment modeling. There are many possible ways for assessment to be integrated and degrees of integration. The standard view of integration refers to the causal chain that joins human actions to valued consequences. In assessment of climate change, this means assessment that considers the social and economic factors that drive emissions, the biogeochemical cycles and atmospheric chemistry that determine the fate of emissions, the resultant effect of emissions on the climate globally and locally, and the impacts of climate change on managed and unmanaged ecosystems, and consequently on human activities and welfare. This view is commonly called "end-to-end" integration. It is reflected in the widely held view that integrated assessment of climate change implies analysis of emissions and impacts simultaneously.

Several studies have examined the interconnectedness of environmental and socioeconomic factors. These studies have used a wide range of statistical and mathematical tools. None of the studies reviewed used the Linear Structural Relations (LISREL) modelling tool proposed in this study. Moreover, studies that compared interrelationships between socioeconomic and environmental factors across many countries of different socioeconomic background are scanty. Comparison of such nature is useful for directing domestic environmental management strategies to high priority issues and to effectively negotiate on international scenes.

The purpose of this study is to examine causal linkages and interrelationships between selected socioeconomic and environmental variables (see Fig. 1). The study: i) will show specific factors or variables on which policy makers or decision makers should focus if the goal is to improve environmental performance and economic growth, ii) provide empirical evidence that would allow identification of important variables for inclusion into integrated assessment modelling, and iii) provide information on the role of key socioeconomic and environmental variables on the future of the economy and society.

Fig. 1. General Model of Casual Linkages and Interrelationships Between Socioeconomic and Environmental Variables



Acronyms:

GDP- gross domestic product; **Fish**- total fish catches (‘000 tonnes); **forest**- forest cover (‘000 hectares); **forharv**- forest harvest in 1000m3; **motveh**- motor vehicles in use (‘000); **enrcon**- total final consumption of energy (mill tonnes of oil equivalent);**enerSup**- total primary energy supply (mill tonnes of oil equivalent); **publicRD**- public spending for environmental protection (mill US$); **popul**- total population (mill); **land**-total land area (‘000 hectares); **SO2, Particul, NOX, VOCs, and CO2**- emissions of sulphur dioxide, particulate matter, nitrogen oxides, volatile organic compounds, and carbon dioxide in metric tonnes; **Debt**- Gross external public debt (mill US$); **valagri**- value of agricultural production; **Airindex**- an air quality index; **Temper**- temperature in degree Celsius; **Rainfall**- rainfall in mm; and error(?) indicate regression errors associated with endogenous variables.

The Empirical Model

Structural equation models have been used in several areas of the social and behaviourial sciences (Joreskog and Sorbom, 1989). A structural equation model can be used to examine a phenomenon in terms of cause-effect variables and their indicators. Equations in this model represent a causal link and estimates of structural parameters may not coincide with the coefficients obtained from ordinary regression analysis. Structural parameters represent some relatively "accurate" features of the mechanism that generates the observed variables (Joreskog and Sorbom, 1989). Moreover, the linear structural relations model is designed to overcome problems associated with measurement errors and causal relationships.

The LISREL model chosen in this study is used to examine causal relationship between independent (exogenous) and dependent (endogenous) variables. Consider random vectors $\eta = (\eta_1, ...\eta_m)$ and $\zeta = (\zeta_1,...\zeta_n)$ of latent dependent and independent variables, respectively. The linear structural equation can be specified as:

$$\eta = \beta\eta + \Gamma\zeta + \acute{\varepsilon} \qquad \text{.................................. (1)}$$

where η and ζ are vectors of latent dependent and independent variables, β (mxm) and Γ (mxn) are

coefficient matrices and $\acute{\varepsilon}$ ($\acute{\varepsilon}_1$, ...$\acute{\varepsilon}_m$) is a random vector of residuals. The elements of β represent the direct effects of η-variables on other η-variables, and the elements of Γ represent direct effects of ζ variables on η-variables. Vectors η and ζ are not observed, but instead vectors Y' (y_1, ...Y_p) and X' (x_1, ... x_n) are observed, such that

$$Y = \Omega_y\eta + u \qquad \text{.................................. (2)}$$
$$X = \Omega_x\zeta + \delta \qquad \text{.................................. (3)}$$

Where u and δ are vectors of uncorrelated error terms (errors of measurement between sets but may be correlated within sets). These equations represent the multivariate regressions of y on η and of x on ζ, respectively.

The full LISREL model is defined by the following three equations:

Structural Equation Model:	$\eta=\beta\eta +\Gamma\zeta + \acute{\varepsilon}$	.... (4)
Measurement Model for Y:	$Y=\Omega_y\eta + u$	.... (5)
Measurement Model for X:	$X=\Omega_x\zeta + \delta$	.... (6)

These equations assume that ζ and $\acute{\varepsilon}$,η and u, ζ and δ are uncorrelated, $\acute{\varepsilon}$,u and δ are mutually uncorrelated and that β has zeros in the diagonal and I-β is non-singular (Joreskog and Sorbom, 1989).

Identification and estimation of parameters of structural equation models depend on forms of β and Γ. Three forms of β can be distinguished: diagonal matrix, triangular and unrestricted elements above and below the diagonal (Joreskog and Sorbom, 1989). The data set examined in this study contains only observed variables and assumed zero measurement error.

Thus, the LISREL model can be formulated as:

$Y = \alpha + \beta y + \Gamma x + \acute{\varepsilon}$ .... (7)

The y's are to be explained by the model. That is variations and covariations among the y-variables are to be accounted for by the x-variables. The x-variables may be random variables or a set of fixed values. The parameter matrices involved in this model are β, Γ and $\Phi = \text{cov}(\acute{\varepsilon})$.

Equation (7) involves the following assumptions: i) $(I-\beta)$ is non-singular, ii) $E(\acute{\varepsilon}) = 0$ where E is the expected value operator, and iii) $\acute{\varepsilon}$ is uncorrelated with x.

If the covariance or correlation matrix is analyzed α may be omitted. Solving for y will give the following equation:

$Y = A\alpha + A\Gamma x + A\acute{\varepsilon}$ .... (8)

Where $A = (I-\beta)^{-1}$. For $\beta=0$, equation seven and eight become identical, and equation seven become a regression equation. When β is sub-diagonal (or when the y-variables can be ordered so that β becomes sub-diagonal) and Φ (a covariance matrix) is diagonal, then equation seven becomes recursive system.

Specification of all kinds of relationships between x's, x's and y's, and between y's for all conceivable variables may result in a lack of convergence even with increases in the number of iterations (Joreskog, et al. 1989; Saris, et al. 1984; Hayduk, 1987). In the present study, based on correlation and regression analysis as well as LISREL convergence criteria, x-variables whose effects on the y's are relatively low were excluded from the analysis.

Measures of Model Fitness

The measures of fitness that are used in this study make use of the minimum discrepancy function. However, they differ with respect to the magnitude of the penalty each measure imposes depending on the level of complexity represented by the model.

CMIN/DF is the minimum discrepancy divided by its degrees of freedom. Several writers have suggested the use of this ratio as a measure of fit. In most cases this value (ratio) should be close to one for correct models. In general, a ratio of chi-square to degrees of freedom of less than five seems to be an acceptable range (see Wheaton et al. 1977, Byrne 1989, Carmines and McIver, 1981, and Marsh and Hocevar, 1985; Arbuckle, J. L. 1997).

The Akaike information criterion (AIC) is given by the sum of the discrepancy function and twice the number of distinct parameters. The Browne-Cudeck Criterion (BCC) imposes a slightly greater penalty for model complexity than does AIC. The criterion is that the model with the smallest value of the ratio, AIC and BCC should be selected to investigate the problem identified by the study.

Sources of Data and Variable Definitions

Time series data on socioeconomic and environmental data are difficult to gather. Even when available, the units of measurements may not be the same. Substantial effort was devoted to validating the data prior to the analysis. Most of the data was gathered from OECD Compendium of Environmental Data, FAO, IMF, and Environment Canada hard copy and electronic publications.

The data was divided into seven categories: i) North America (Canada and USA), ii) Asia/Pacific (Japan and Australia), iii) Atlantic regions of Western Europe (UK and Ireland), iv) Southern Regions of Western Europe (Spain, Portugal, France and Italy), v) Eastern regions of Western Europe (Germany, Switzerland, and Austria), vi) Central regions of Western Europe (Denmark, Norway, Belgium, the Netherlands, Finland, Sweden), vii) Western Europe, and viii) all OECD countries. The criteria for grouping of countries are geographical proximity and performance of countries in environmental improvements.

Several variables were examined in undertaking this study. Many variables were discarded due to statistical problems such as lack of convergence and collinearity. After repeated trials, the following variables were selected to investigate causal linkages and interrelationships between socioeconomic and environmental variables. These include value of crop production (mill US$), GDP(bill US$), value of livestock production (mill US$), total fish catches (‘000 tonnes), forest cover (‘000 hectares), forest harvest ($1000m^3$), motor vehicles in use (‘000), total final consumption of energy (mill tonnes of oil equivalent), total primary energy supply (mill tonnes of oil equivalent), public spending for environmental protection (mill US$), passenger cars in use (‘000), total population (mill), total land area (‘000hectares), tractors (‘000), emissions of SO_2, PM, NO_x, VOCs and CO_2 (all in metric tonnes), and gross external public debt (mill US$). To improve on model performance, the value of crop and livestock productions were added to create a variable called valagri (value of agricultural production). Moreover, motor vehicles, passenger cars and tractors were added to form a variable called motveh. Furthermore, to capture the joint impact of emissions of pollutants (NO_x, SO_2, VOCs, PM, and CO_2), an air quality index was constructed using the following formula:

$$\text{Air Index}_t = \sum_{i=1}^{5} E_{it}/E_{i,r,max} \qquad \text{(9)}$$

Where E refers to emissions, i indicates a pollutant, r to region and t refers to years. The formula indicates that the air quality of a given region in any year is approximately equal to the ratio of emissions of a pollutant to the maximum emissions of the same pollutant in any given year summed over five pollutants. Thus, its value is truncated between zero and five. The higher the value of this index the higher the probability that the air quality of a certain region is bad. This assumes that emission from within a region is the major factor determining air quality of that country. Therefore, it ignores the impact of transboundary pollutants.

Results of the Analysis

The measures of model fitness indicated that the ratio of chi-square to degrees of freedom was less than three for all models. The log-likelihood function was also significant in all cases at 5% level of significance. It means that the representations of casual linkages and relationship are reflective of the true underlying relationships. The results of LISREL analysis for North America, Asia/Pacific, Central and Eastern Regions of Western Europe are presented in Table 1.

North America

Population significantly and positively influences fish catches, energy consumption, and forest harvest. The number of vehicles is positively and significantly associated with energy consumption, forest harvest, GDP and agricultural production. Increases in the number of vehicles imply increased emissions of pollutants that may contribute to acidic deposition. An increase in growth retarding pollutants may contributed to reduced growth and premature harvesting of trees. On the other hand, increases in emissions of NO_x may contribute to enhanced growth of trees and early harvesting.[2]

Expenditure for environmental protection exerts significant and positive impact on emissions of NO_x, and CO_2, but contributes to reduced emissions of VOCs and SO_2. However, its impact on reduction of SO_2 emission is not statistically significant. Energy consumption exerts a positive and significant effect on emissions of PM, SO_2, NO_x, VOCs, CO_2, GDP and debt.

[2] This assertion, however, should be supported by basic science research with respect to the response of trees to depositions of SO_2 and NO_x.

Table 1. Results of LISREL Analysis by Country Group, Based on data from 1980 to 1993.

Pattern of Influence	North America		Asia		Central Europe		Eastern Europe	
	Estimate	C. Ratio	Estimate	C. Ratio	Estimate	C. Ratio	Estimate	C. Ratio
Air index <-------- debt	0.024	2.832	-0.252	-0.661	0.003	1.555	0.207	2.679
Air index <----- EnerCon	0.005	10.215	0.005	5.586	0.064	9.08	0.038	9.216
Air index <--------- GDP	0.349	4.105	0.209	2.552	0.154	2.231	0.302	2.979
Air index <--------- PublicRD	0.001	1.105	-0.251	-2.912	-0.561	-4.231	-0.321	-2.979
CO_2 <---------- EnerCon	2.861	5.471	0.631	2.318	2.321	3.366	1.183	4.61
CO_2 <---------- FORHARV	0.402	4.243	0.012	2.239	0.201	1.99	0.209	2.33
CO_2 <-------------- GDP	0.06	3.582	0.079	3.248	-0.066	-11.294	0.118	2.159
CO_2 <--------- PublicRD	0.426	2.243	0.238	2.962	-1.37	-3.855	-0.877	-0.654
debt <--------- EnerCon	0.021	2.592	-0.021	-2.121	1.154	3.734	0.133	5.089
debt <------------- GDP	0.004	1.403	0.004	1.223	-0.056	-4.248	0.009	3.013
debt <-------- PublicRD	2.158	1.232	2.226	1.343	4.844	1.271	3.207	3.934
EnerCon <--------- Land	0.001	4.728	0.001	5.414	0.007	5.255	-0.006	-7.62
EnerCon <------- Motveh	0.419	6.559	-0.001	-3.006	0.002	3.896	0.402	2.89
EnerCon <-------- POPUL	0.355	4.558	0.879	6.116	0.203	4.054	0.401	4.243
EnerCon <------- Temper	-2.686	-8.249	-0.781	-2.148	-0.658	-6.484	-1.081	-3.425
Fish <------------- NOx	-0.024	-0.242	-0.435	-9.666	-0.07	-0.046	-0.125	-2.145
Fish <----------- POPUL	0.058	33.126	0.058	33.313	-0.11	-2.199	0.001	0.143
Fish <------------- SOx	-0.413	-4.062	N.A.	N.A.	-1.228	-4.289	-0.056	-3.109
FORHARV <------- Motveh	-3.878	-7.665	-1.032	-3.663	1.499	5.044	1.585	2.604
FORHARV <---------- NOx	3.973	6.535	1.81	2.91	-1.318	-2.765	-1.264	-5.388
FORHARV <-------- POPUL	2.418	5.554	2.273	5.227	-0.842	-2.474	-2.265	-4.556
FORHARV <---------- SOx	-2.948	-9.211	N.A.	N.A.	2.529	6.39	2.438	5.666
GDP <---------- EnerCon	3.909	8.312	2.62	6.433	0.828	2.53	2.17	3.848
GDP <------------- Fish	0.009	0.868	0.034	2.357	-0.006	-1.736	-0.48	-1.359
GDP <---------- FORHARV	0.205	7.311	0.003	7.763	0.001	3.017	0.031	2.846
GDP <----------- Motveh	0.096	2.368	0.084	2.486	0.136	2.236	-0.018	-0.624
GDP <------------ POPUL	-0.001	-0.825	-0.002	-2.011	-0.049	-11.148	0.261	4.278
GDP <--------- PublicRD	0.063	1.226	0.632	4.498	3.741	9.237	1.809	3.328
GDP <---------- Valagri	-0.01	-3.326	-0.007	-2.307	0.018	7.283	-0.289	-3.582
NOx <---------- EnerCon	2.722	10.276	1.585	3.963	1.703	4.423	2.25	8.054
NOx <-------------- GDP	1.478	4.809	1.154	7.623	-0.207	-9.781	0.457	2.435
NOx <--------- PublicRD	0.364	3.536	0.489	2.841	-0.826	-3.134	-0.92	-2.701
Particul <----- EnerCon	1.381	6.83	N.A.	N.A.	1.174	3.081	1.915	6.157
Particul <--------- GDP	0.786	2.209	N.A.	N.A.	-0.25	-2.955	0.487	3.802
Particul <---- PublicRD	-0.084	-1.52	N.A.	N.A.	-1.822	-5.935	-1.23	-4.473
SOx <---------- EnerCon	2.394	5.648	N.A.	N.A.	1.857	3.202	1.395	4.721
SOx <-------------- GDP	0.914	2.614	N.A.	N.A.	0.07	1.37	1.399	5.098
SOx <--------- PublicRD	-0.35	-1.62	N.A.	N.A.	-1.338	-6.928	-0.538	-2.83
Temper <------ Air index	1.491	11.457	1.472	9.845	0.817	4.015	2.501	6.321
Temper <----------- CO_2	0.008	5.048	0.008	4.599	-0.001	-0.164	-0.007	-0.824
Temper <------- FORHARV	0.449	8.096	0.002	7.642	0.0498	2.933	0.029	1.952
Temper <----------- NOx	0.004	7.578	0.004	8.889	0.016	6.018	-0.003	-0.685
Temper <---------- VOCs	0.001	1.488	N.A.	N.A.	0.002	1.589	0.01	2.666
Valagri <--------- Land	0.385	3.37	0.38	3.425	-4.97	-10.32	-2.289	-8.276
Valagri <------- Motveh	0.146	3.364	0.196	5.457	-0.363	-9.762	0.349	7.833
Valagri <---------- NOx	-2.631	-6.716	4.175	9.384	14.273	12.026	2.858	3.045
Valagri <-------- POPUL	0.015	1.85	0.026	4.259	0.373	8.906	0.043	1.768
Valagri <------- Temper	4.101	12.665	2.355	7.201	1.517	4.2	1.252	3.836
Valagri <--------- VOCs	1.912	5.272	N.A.	N.A.	-6.278	-11.867	0.008	0.009
VOCs <--------- EnerCon	2.42	14.695	N.A.	N.A.	1.319	9.578	3.976	7.704
VOCs <--------- FORHARV	0.906	4.738	N.A.	N.A.	0.003	0.816	0.004	2.642
VOCs <------------- GDP	1.444	5.264	N.A.	N.A.	-0.032	-0.724	0.489	2.682
VOCs <-------- PublicRD	-0.81	-2.417	N.A.	N.A.	-0.513	-0.9	-10.249	-1.678

Emission of CO_2 is positively and significantly associated with increased temperature. Forest harvest contributes to increases in emission of CO_2 and VOCs. Growth in the economy (GDP) reduces emissions of PM, SO_2, VOCs, NO_x and CO_2. Debt is positively associated with air quality. Increases in external public debt may result in less spending for environmental improvements, thus contributing to deterioration in air quality.

Emissions of SO_2 and NO_x contribute to reductions in fish catches but to increases in forest harvest (see footnote # 1). Emission of VOCs and NO_x exert negative impact on agricultural production. Temperature exhibits statistically significant and negative impact on energy consumption. Emission of NO_x is significantly and positively associated with increased temperature. An increase in temperature seems to exert a significant and positive impact on agricultural production.

Economic growth (GDP) contributes to deterioration of air quality while the later significantly and positively influences temperature. Energy consumption significantly and positively influences the measure of air quality. That is, it contributes to deterioration of air quality.

Asia/Pacific Countries

Population exerts a significant and positive impact on fish catches, energy consumption, agricultural production and forest harvest. The number of vehicles negatively and significantly influences forest harvest and energy consumption, but exert a positive impact on GDP and value of agricultural production.

Spending in environmental protection significantly and positively influence economic growth (GDP), and emissions of NO_x and CO_2. Energy consumption positively and significantly influences emissions of NO_x, CO_2, GDP and debt. Growth in the economy exerts significant and positive impact on emissions of CO_2 but contributes to reduced emissions of NO_x, and deterioration of air quality. Emission of CO_2 increases temperature. Forest harvest is positively and significantly related to increases in emissions of NO_x but negatively related to temperature. Debt is negatively associated with the air quality index. Reduced debt or enhanced economic growth contributes to greater emissions and hence deterioration of air quality unless significant spending is made for environmental improvements. Emission of NO_x

contributes to reduced fish catches, agricultural production, and temperature. Temperature is negatively and significantly related to energy consumption, but positively related to agriculture.

Central Regions of Western Europe

The larger the population the smaller the amount of fish catches. Population positively and significantly influences energy consumption and agricultural production. However, growth in population is associated with declining forest harvest. In countries where the growth in population or population per unit of forest resources is higher, the emphasis on maintaining resources for future generation tend to be more important (politically) than in larger and more resource-based regions such as North America, Asia/Pacific and Southern regions of Western Europe. This may be the reason for the negative impact of population on forest harvest. The number of vehicles significantly and positively influences energy consumption but negatively associated with agricultural production.

Spending for environmental protection (SEP) positively and significantly influence growth in the economy (GDP). SEP contributes to the reduction of emissions of SO_2, CO_2, PM, NO_x and VOCs with statistically significant impact on the first three pollutants. Energy consumption positively and significantly influences emissions of SO_2, NO_x, VOCs, CO_2 and PM. Furthermore, increases in energy consumption contribute to increases in gross public debt and GDP. On the other hand, GDP negatively and significantly influence emissions of PM, CO_2, NO_x, and gross public debt.

Emissions of SO_2 and NO_x exert negative impacts on fish catches. Forest harvest significantly contributes to increases in emissions of CO_2, temperature, and GDP. The result also indicated that emissions of SO_2 and NO_x are positively associated with forest harvest. Increases in emissions of CO_2 contribute to increases in temperature. Emissions of VOCs contribute to reduced value of agricultural production while emissions of NO_x exert positive impact on agricultural production.

Emission of NO_x and VOCs is positively associated with temperature. Temperature significantly and negatively influence energy consumption, and but contributes to increased value of agricultural production. Energy consumption positively and significantly influences the magnitude of the air quality or air pollution.

Eastern Regions of Western Europe

Increase in population positively influence energy consumption and GDP but contributes to declining forest harvest. Increasing number of the population may have become aware of the dangers of losses of forests, hence consciously reduced harvesting of trees. The number of vehicles positively and significantly influences agricultural production and forest harvest. Holding everything constant, spending for environmental protection may have an immediate negative impact on increasing fiscal deficit or debt because its benefits may not be realized in a short period of time. The findings of this study show that spending for environmental protection contributes to increases in debt. Spending for environmental protection help to reduce emissions of SO_2, NO_x, VOCs, CO_2 and PM, but with significant impact only on PM.

Energy consumption positively and significantly influences emissions of PM, SO_2, NO_x, VOCs, CO_2, GDP and debt. Debt is positively related to air quality. Growth in GDP exerts a positive and significant impact on emissions of PM, SO_2, VOCs, CO_2, and NO_x. Emission of CO_2 contributes to increases in temperature. Forest harvest shows positive influences on emissions of CO_2 and VOCs. Forest harvest exerts a positive and significant impact on temperature, while the later is positively associated with emissions of VOCs.

Emission of SO_2 and NO_x seem to exert a negative impact on fish catches. Emissions of SO_2 significantly and positively influence forest harvest while the later is negatively influenced by emission of NO_x. Agricultural production seems to be positively influenced by emission of NO_x. An increase in temperature contributes to reduced energy consumption.

Western Europe

The result of LISREL analysis for Southern, Atlantic regions and all of Western Europe, and OECD countries is presented in Table 2. Population exerts significant and positive impact on energy consumption and value of agricultural production, but negatively and significantly associated with forest harvest and GDP (Table 2).

Motor vehicles exert significant and positive impact on energy consumption, GDP, value of agriculture and forest harvest. Spending for environmental protection significantly and negatively influences emission of SO2, CO2, VOCs and PM. However, environmental protection is positively and significantly associated with growth in GDP. Moreover, spending for environmental protection is positively and significantly associated with debt. Energy consumption positively and significantly influenced by motor vehicles and population. It is negatively and significantly influenced land and temperature.

Fish catches is negatively and significantly influenced by emissions of SO_2 and NO_x. Forest harvest is positively and significantly influenced by motor vehicles and emission of NO_x but negatively influenced by population and SO_2. GDP is positively and significantly influenced by energy consumption, numbers of vehicles and environmental protection, but negatively and significantly influenced by population and agricultural production.

Emissions of NO_x, PM, SO_2, and CO_2 are positively and significantly influenced by energy consumption. GDP also exerts positive impact on emissions of these pollutants. Spending for environmental protection contributes to reduction of emissions of SO_2.Temperature increases with deterioration in air quality, increases in emissions of CO_2 and VOCs, and forest harvest, and declining rainfall. Agriculture is negatively influenced by emissions of NO_x and VOCs but positively influenced by vehicles, population and temperature. Emission of VOCs positively impacted by energy consumption but negatively associated the forest harvest. Air quality is positively and significantly influenced by energy consumption and GDP.

Table 2. Results of LISREL Analysis by Country Group, Based on data from 1980 to 1993.

Pattern of Influence	All Western		Southern Europe		Atlantic Europe		OECD	
	Estimate	C. Ratio	Estimate	C. Ratio	Estimate	C. Ratio	Estimate	C Ratio
Air index <-------- debt	0.002	0.178	-0.008	-1.751	0.007	6.412	0.521	2.832
Air index <----- EnerCon	0.029	2.758	0.018	4.653	0.043	2.775	0.005	2.215
Air index <--------- GDP	0.001	3.799	-0.001	-2.064	0.001	2.439	0.393	4.105
Air index <---- PublicRD	-0.341	-2.798	-0.289	-3.951	-0.242	-5.026	-0.145	-2.954
CO_2 <---------- EnerCon	2.197	7.621	1.776	15.414	N.A.	N.A.	2.861	5.471
CO_2 <---------- FORHARV	0.041	2.236	0.001	4.737	0.098	1.987	0.032	2.243
CO_2 <-------------- GDP	0.188	2.127	0.018	0.849	0.041	3.51	0.06	3.582
CO_2 <--------- PublicRD	-1.125	5.377	-0.645	-2.785	-1.842	-6.013	1.26	2.243
debt <--------- EnerCon	-0.104	-1.74	-0.383	-3.723	N.A.	N.A.	-0.021	-2.592
debt <------------- GDP	0.066	1.98	0.057	4.359	-0.037	-2.037	0.004	1.403
debt <-------- PublicRD	1.205	2.237	0.561	0.252	0.237	3.09	2.158	1.232
EnerCon <--------- Land	0.001	3.998	-0.028	-2.478	-0.828	-3.543	0.001	4.728
EnerCon <------- Motveh	0.005	4.4	-0.0074	-1.817	0.102	2.312	0.031	6.559
EnerCon <-------- POPUL	0.209	4.801	0.011	2.318	0.003	3.23	0.231	4.558
EnerCon <------- Temper	-0.582	-9.202	0.177	0.895	N.A.	N.A.	-0.686	-8.249
Fish <------------- NO_x	-0.185	-2.53	-0.671	-8.126	-.365	-2.849	-0.024	-0.242
Fish <----------- POPUL	0.001	0.327	0.019	8.127	N.A.	N.A.	0.058	3.126
Fish <------------- SOx	-0.289	-2.964	-0.294	-5.081	-0.237	-2.653	-0.413	-4.062
FORHARV <------- Motveh	3.163	8.06	-1.882	-7.531	N.A.	N.A.	-3.878	-9.665
FORHARV <---------- NO_x	1.483	4.323	1.903	5.601	0.003	1.969	1.973	6.535
FORHARV <-------- POPUL	-1.862	-7.514	2.62	6.051	-0.087	-3.641	2.418	3.554
FORHARV <---------- SOx	1.254	2.821	-0.21	-1.395	-0.008	-2.001	2.948	9.211
GDP <---------- EnerCon	1.543	2.534	0.545	2.343	N.A.	N.A.	2.909	13.312
GDP <------------- Fish	0.023	1.844	N.A.	N.A.	N.A.	N.A.	0.009	0.868
GDP <---------- FORHARV	0.004	0.98	N.A.	N.A.	N.A.	N.A.	0.005	1.311
GDP <----------- Motveh	0.073	2.975	0.025	4.057	0.089	2.155	0.096	2.368
GDP <------------ POPUL	-0.011	-2.247	0.002	1.546	-0.02	-4.494	-0.001	-0.825
GDP <--------- PublicRD	1.808	4.771	0.021	1.983	.039	1.69	0.363	1.226
GDP <---------- Valagri	-0.025	-2.143	N.A.	N.A.	0.003	2.019	-0.01	-3.326
NO_x <---------- EnerCon	1.903	6.058	2.494	4.552	2.536	9.027	2.722	10.276
NO_x <-------------- GDP	0.925	2.667	0.918	4.501	-0.984	-1.191	-1.478	-4.809
NO_x <--------- PublicRD	0.307	0.633	1.304	4.458	0.087	2.979	1.364	3.536
Particul <----- EnerCon	3.792	15.297	0.056	2.42	N.A.	N.A.	2.381	6.83
Particul <--------- GDP	0.169	11.332	N.A.	N.A.	N.A.	N.A.	0.786	2.209
Particul <---- PublicRD	-0.379	-2.841	0.001	1.655	0.037	4.277	-0.384	-1.52
SOx <---------- EnerCon	0.932	4.136	0.888	2.573	N.A.	N.A.	1.394	3.648
SOx <-------------- GDP	0.979	5.988	-0.697	-1.428	0.588	4.349	0.914	3.614
SOx <--------- PublicRD	-0.605	-4.903	1.695	3.263	-0.209	-2.992	-0.35	-2.62
Temper <------ Air index	0.917	2.47	0.705	2.61	1.404	4.298	2.491	11.457
Temper <----------- CO_2	0.307	3.169	-0.021	-1.054	0.033	7.606	0.008	5.048
Temper <------- FORHARV	0.549	2.737	0.298	2.949	0.007	1.407	0.275	3.096
Temper <----------- NO_x	0.035	1.74	0.016	3.207	0.001	1.514	0.034	7.578
Temper <------ Rainfall	0.056	2.911	0.084	5.315	0.099	4.537	-0.066	-5.951
Temper <---------- VOCs	0.005	8.164	0.229	3.31	0.002	2.868	0.001	1.488
Valagri <--------- Land	-1.303	-1.012	1.159	4.353	N.A.	N.A.	0.385	3.37
Valagri <------- Motveh	0.281	6.076	0.599	4.746	0.185	6.933	0.146	3.364
Valagri <---------- NO_x	-1.319	-3.427	-1.416	-3.958	-1.877	-7.227	-231	-3.716
Valagri <-------- POPUL	0.41	1.94	0.146	3.631	0.104	3.898	0.015	1.85
Valagri <------- Temper	1.336	5.127	-0.376	-2.437	N.A.	N.A.	1.601	5.665
Valagri <--------- VOCs	-1.773	-3.189	1.641	4.222	-1.7	-6.137	-1.912	5.272
VOCs <--------- EnerCon	1.557	9.308	1.056	4.404	N.A.	N.A.	1.42	4.695
VOCs <--------- FORHARV	0.003	2.734	0.013	4.061	0.477	2.085	2.006	4.738
VOCs <------------- GDP	0.003	0.033	0.34	2.499	-0.062	-1.191	1.474	5.264
VOCS <-------- PublicRD	-1.499	-5.932	-1.979	-4.064	0.108	1.985	-1.81	-4.417

Southern Regions of Western Europe

Debt, energy consumption and GDP exert positive impacts on air quality. Expenditures for environmental protection exert negative and significant impact on air quality. Energy consumption increases emission of CO_2, NO_x, PM, SO_2 and VOCS. However, it is negatively associated with debt. If energy is used inefficiently, then net gain from energy consumption may be neagtive to such an extent that it may increase fiscal deficit or debt. That may be the reason for the neagtive assocaition between energy consumption and external public debt.

Forest harvest contributes to increased emissions of CO_2. Fish catches is negatively impacted by emissions of NO_x and SO_2 but positively by population. Forest harvest declined due to SO_2 emission but increased due to NO_x emissions. Emission of CO_2 and NO_x, and forest harvest contributes to increased temperature. Agricultural production seems to be negatively affected by emissions of NO_x and temperature, but increased due to increases in the number of vehicles.

Atlantic Regions of Western Europe

Spending for environmental protection and GDP is negatively associated with improved air quality. However, energy consumption and debt seem to contribute to deterioration of air quality. An increase in GDP is associated with declining debt. Debt seems to increase with increase in spending for environmental protection.

Forest harvest contributed to increased emissions of CO_2. Emissions of NO_x and SO_2 contribute to declining fish catches. Forest harvest is associated with increases in NO_x emissions but declines with emissions of SO_2. Spending for environmental protection contributes to declining emissions of CO_2 and SO_2 but to increases in emissions of NO_x and VOCs. Population exerts significant impact on energy consumption. Vehicles exert positive impact on energy consumption, GDP and value of agricultural production. Emission of CO_2 contributes to increases in temperature.

OECD Countries

Air quality deteriorated due to increases in external public debt, economic growth and energy consumption but improved as a result of spending for environmental protection. Energy consumption also contributes to increases in emissions of CO_2, NO_x, SO_2, PM and VOCs. Similarly, economic growth exerts positive impact on emission of CO_2, SO_2, NO_x, PM and VOCs.

The number of vehicles contributes to increases in energy consumption, GDP and value of agricultural production. Forest harvest is positively impacted by emissions of NO_x and SO_2. Fish catches decline with increases in emission of NO_x and SO_2. Forest harvest increases emission of CO_2 but the latter also increases temperature.

Conclusions

The conclusion that emerges from this study is that most of the variables considered are important in designing sustainable environmental management. Air quality (combined index based on five pollutants) seem to increase (poor air quality) due to increases in debt, energy consumption and GDP. However, spending for environmental protection contributes to reducing this deterioration. The greatest positive impact of spending for environmental protection is observed in the Central and Eastern Regions of Western Europe.

The study also indicates that spending for environmental protection is associated with increases in economic growth in Asia/Pacific, Central and Eastern regions of Western Europe. In other regions either the results are statistically insignificant or negative. On the other hand, the findings of this study show that spending for environmental protection increases debt in almost all regions. It means that benefits for environmental protection would be realized in the long term. Therefore, short term gains could be negative, contributing to fiscal deficit or debt. Increases in emissions of pollutants such as SO_2 may contribute to increases in forest harvest. The reason may be that harvested forest is accelerated due to either fast or retarded growth of trees due to emissions of SO_2 and NO_x. On the other hand, fish catches seem to decline with increases in emissions of SO_2 and NO_x. The later variables contribute to acidic deposition that may affect the health of aquatic ecosystem.

While economic growth is positively influenced by energy consumption, the later contributes to increases in emissions of pollutants. It seems, therefore, that improved air quality and environment can be obtained through finding a balance between spending for environmental protection and economic growth or energy consumption. It also implies that much has to be done in reducing energy consumption. However, the nature of strategies has to take into account region-specific characteristics. For example, the impact of temperature and land area on energy consumption are substantially larger and significant in Canada than anywhere else. Therefore, sound, targeted and region-specific strategies ought to be designed to ensure sustainable environment.

Preliminary findings of this study suggest that I) exploring the impacts of variables included in this study in a dynamic macroeconomic setting, such as general equilibrium models, may provide an overall socioeconomic impacts of linkages between environmental and socioeconomic variables, ii) causality analysis among natural resources, emissions of pollutants, environmental quality and economic growth should be explored to better understand the dynamics of interaction between environmental and socioeconomic factors, and iii) development of a database that includes variables examined in the present study and other relevant variables is important to gain a better understanding of economy-environment linkages and to develop empirical evidence for bilateral and multilateral environmental agreements.

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References

Arbuckle, J. L. *AMOS User's Guide, Version 3.6*. SmallWaters Corporation, 1997..

CDIAC. *Carbon Dioxide Information Analysis Center. Public Archives on Time Series temperature and Rainfall Data*, Oak Ridge National Laboratory, TN, 1996.

Environment Canada. *The NEIPTG Consensus national Base case Forecast*, March, Ottawa, 1996.

Goldberger, A.S. and Duncan, O.D. *Structural Equation Models in the Social Sciences (eds)*. New York: Seminar Press, 1973.

Hayduk, L.A. *Structural Equation Modelling with LISREL: Essentials and Advances*. Baltimore: John Hopkins University Press, 1987.

Joreskog, K.G. *Scandinavian J. of Statistics.* 1981, 8, 65-92.

Joreskog, K.G. and Sorbom, D. *Advances in Factor Analysis and Structural Equation Models.* Cambridge: Abt Books, 1979.

Joreskog, K.G. and Sorbom, D. *LISREL 7. A Guide to the Program and Applications*. Chicago: SPSS Inc., 1989.

OECD. *OECD Environmental data (1995 Compendium)*. Paris, 1995.

Sarris, W.E. *Causal Modelling in Non-Experimental Research: An Introduction to the LISREL Approach.* Amsterdam: Sociometrics Research Foundation, 1984.

Theil, H. *Principles of Econometrics*. New York: Wiley, 197.