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ABSTRACT

There has been a lot of debate regarding the impact of emissions of pollutants on human health and the environment. Epidemiological studies tend to show the impact of increased ambient concentrations of pollutants on increased hospital admissions, mortality, morbidity, respiratory problems, etc. Without controlled experiments that compare people who are exposed to contaminants to those who are not, it is impossible to predict the causes and effects with certainty. Nevertheless, estimates of human and environmental health benefits from improved air quality indicate that there are associations between ambient concentrations of contaminants, human health and environmental impacts.

The present study examines the linkages between human health, environmental quality, and emission of pollutants and selected socioeconomic variables for selected OECD regions. Path or causal models will be constructed using health, socioeconomic and environmental parameters to determine the direction of causal relationships, their magnitude and possible implication for public policy making. This analysis will be performed for the OECD countries, and selected regions of the OECD (North America, the Pacific Rim, and Europe). Comparative analysis of the relationships between human health, socioeconomic and environmental variables among the OECD countries will indicate, among other things, i) whether or not environmental quality is an important determinant of human health, ii) whether or not spending on health care system is significantly influenced by indicators of health status that are included by environmental variables, and iii) which socioeconomic variables are significantly associated with indicators of human and the environment health.

1. INTRODUCTION

The Oxford English Dictionary defines environment as "conditions under which any person or thing lives and develops; the sum total of influences which modify and determine the development of life or character." Almost everything that influences health other than genetic make-up, perhaps even that fits this definition: the environment is the most important determinant of health. The environment, therefore, includes all living things including humans. Needless to say that it is human endeavor for better life that endangers the delicate balance between the environmental quality and human health.

Pollution poses a serious threat to human health and the environment worldwide. It contributes significantly to regional and global atmospheric issues such as global warming, acidification and depletion of the ozone layer. It affects all living things, including all kinds of vegetation on which humans depend for survival. Changes to the natural environment pose threats to human health. These threats may include increased incidences of infections and epidemics due to immunosuppressive impacts, sunburn and premature aging of the skin due to direct dermatological effects, melanocytic (malignant) and squamous and basal cell neoplasias (skin cancers); etc.[1,2,3]

Ninety-five percent of the air by weight that is used by living things, including humans, is contained in the Troposphere. This atmospheric layer is polluted by primary pollutants such as carbon monoxide, carbon dioxide, nitric oxide, nitrogen dioxide, sulfur dioxide, etc. and by secondary pollutants such as sulfite, nitric acid, sulfuric acid, etc. Therefore, protecting the biogeophysical environment is crucial to improvements in human health.[1,2,3]

Analysis of the likely impacts of implementing particular activities (arising from policies, programs, projects, etc.,) on the biogeophysical environment and human health and welfare forms the foundation for improvements in indicators of environmental and human health. Much effort is now directed toward the identification, control and elimination of environmental risk factors. However, these risk factors are created by human activities. For example, increased industrial activity that led to increased emissions of pollutants make up a significant portion of the environmental risk factors.[1,2,3]

Improvements in the health of populations depend on stability of climate, protection from solar ultraviolet radiation, adequate supplies of food and fresh water, and maintenance of biodiversity. Adverse environmental conditions may affect the health of the general population. Potential health effects comprise nutritional problems, physical and mental disease, injuries, poisoning and death. The type and degree of effects that may occur in a population depend not only on the potential for exposure to certain environmental factors, but also on the interaction with other variables such as urbanization, industrialization, sanitation conditions, transport activities and climate. The comparison of health status indicators both within and between countries can highlight differences and changes in prevailing environmental conditions and may also be useful in characterizing the role of specific risk factors.[1,2,3]

Human health risks are ubiquitous (home, work, outdoors, indoor, etc.). The cause of human health risk could be physical and social, although the types and combinations can vary markedly between countries and for individuals within the same country. Some of the important environmental diseases and hazards are: (a) infections arising from pathogens in polluted water, food, milk, etc.; (b) respiratory infections due to crowding and poverty; (c) vector-borne diseases associated with diverse ecological factors and conditions; (d) parasitic infections flourishing under ecological conditions which favor intermediate hosts; (e) chronic obstructive lung disease through exposure to dust; (f) cancer and birth defects induced by radiation and organic chemicals, including pesticides and petrochemicals; and (g) mental and psychological disorders arising from social stress, such as the breakdown of traditional lifestyles, unemployment and mass migration.

The impact of these diseases can be felt in two ways: reduced life expectancy and/or death, and reduced productivity. Regardless of which way the consequences are felt, a substantial amount of spending is required to treat illness or symptoms of illness, and improve environmental quality.[1,2,3,4]

Sustainable development implies that the resources used in the production process and the outputs produced should be such that the future generation should be left with at least the same bundle of resource endowment. Unsustainable use of resources that may contribute to increased waste and adverse environmental and human health implies that the future generation will not enjoy the same standard of living as the present generation. Therefore, policy makers of each country have to identify causal factors of current environmental and human health problems in order to implement sound preventive strategies. The present study is intended to identify some of the driving forces that may endanger the well being of the environment and human health.

2. The Problem

Rapid development has been marked with increases in air pollution and occupational exposure since the industrial revolution. The industrial revolution has brought substantial increases in diseases or illnesses associated with environmental pollution. Several studies have confirmed that environmental pollution poses serious threats not only to human health but also to ecosystems.[1,2,3,5,6,7]

It was found that although pollution is a significant contributor to lung cancer mortality, other factors such as occupational exposures and various social factors are of at least comparable importance.[3,4] Air pollution was also found to be associated with acute increased mortality from cardiopulmonary conditions and morbidity such as hospital admissions for related diseases. High levels of air pollutants (primarily particulates and SO_2) may increase mortality in sensitive parts of the population.[3,4,5,6] The same degrees of associations were observed between air pollution levels and prevalence of respiratory diseases as well as lung function disturbances in adults and children. Ozone and sulfur dioxide exposures were also significantly associated with increased emergency visits for asthma. Furthermore, significant increases in non-surgery outpatient visits were observed in association with increases in sulphate concentration. [2,3,4,5,6] Similar studies have confirmed that mortality was significantly associated with PM, NO_x, SO_2, and CO. [2,3,4,5,6,7,8,9,10,11]

Other studies have attempted to relate human health with socioeconomic and environmental variables. For example, it was found that air pollution effects on health maybe partly determined by specific mixtures of air pollutants and may be altered by other environmental, behavioral, and social patterns.[7,8,9,10]

Humans are regarded as the cause and recipient of impacts of environmental pollution or degradation.[1,2,3] If progress is to be made with respect to improved environmental quality, the first course of action ought to be to influence human activity and the driving forces of these activities. In order to influence behavior, appropriate intervention strategies should be designed. These intervention strategies can broadly be divided into two: i) market-based, and ii) non-market-based.

Markets can be used to influence behavior through internalizing costs of damages to resources and the environment. These internalized costs would be revealed through prices of good and services. The problem, however, is that there may not be markets for all environmental goods and services. This is due to the fact that either costs of environmental pollution are not internalized in product prices, or environmental goods and services cannot be quantified. Under this situation, interventions by governments can be used to create markets. However, markets may not always be effective to influence behavior of individuals. This may be due to market imperfections, institutional, social, etc. barriers. Therefore, other options have to be pursued.

The non-market approach could involve regulations, voluntary mechanisms, education, etc. An important driver that may bring a lasting difference with respect to behavior of individuals is to educate the public. One way of educating the public is to make information available with respect to the causes of environmental degradation and their impact on health and economic growth. In order to educate the public, sound analysis of the linkages between socioeconomic, environmental and human health parameters needs to be conducted. The present study is intended to examine these causal linkages for OECD countries, Europe, North America and the pacific Rim. To date, there are no studies that have examined the linkages between socioeconomic, environmental and human health variables at the OECD or sub-continent level using the method proposed in this study. The findings of this study are expected to provide useful information or evidence on the causal linkages and relationships between socioeconomic, environmental and human health variables at regional or continental level.

Development of national environmental and human health policies could be seriously affected if the causes of environmental pollution and human health risk are originating from other countries or continents. Under this situation, it is necessary to examine causative linkages and relationships between socioeconomic, environmental and human health variables at the continental or subcontinent level. Evidence from this kind of analysis, though by no means accurate, could facilitate bilateral and multilateral negotiations to develop a strategy that help minimizes the health risk factors, especially those related to the environment. The contribution of the present study, besides methodological, is to add one piece of evidence on the existence and magnitude of causes of environmental pollution and their impact on indicators of human health as well as patterns of expenditure on health care. In order to examine this intricate relationship, a schematic diagram that depicts causal relationships is presented in Figure 1.

3. Methodology

Exposure to elevated concentrations of ambient air pollutants can result in adverse human health effects. Two modes or methods of study are generally relied on to quantify the relationships between pollutants and specific effects. These are human clinical experiments and epidemiological (or community exposure) studies. Each method has limitations as a basis for quantifying the level of adverse effects anticipated in a given human population as a result of exposure. Consequently, care must be taken in deciding which studies are appropriate for assessment of health impacts in a population.[12] Epidemiological studies, for example, depend on adequate exposure data and the ability to adjust for potential confounders. Clinical studies often do not represent the complex mix of pollutants in the atmosphere. Consequently, construction of dose/exposure-response functions is challenging. Another common complication in quantifying expected health impacts of a pollutant mix is lack of adequate ambient monitoring data coupled with little or no knowledge of a population's time and activity profiles.[12]

The first-best method to accurately depict causal linkages and relationships would have been to conduct controlled experiments. However, this approach is not possible when dealing with large population, and the geographic coverage is as large as a country and continent. Therefore, statistical or epidemiological methods would be the preferred approach. Epidemiological studies make use of path analysis in identifying causes of various kinds of illness using health, environmental and socioeconomic data. The present study uses causal analysis, recursive or non-recursive, to examine the intricate relationship between variables depicted in figure 1.

3.1. The Empirical Model

Structural equation models have been used in several areas of the social and behavioral sciences.[13] 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. [13] Moreover, the linear structural relation's 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.[13]

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.[13] 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 $\Phi=\mathrm{cov}(\acute{\varepsilon})$.

Equation (7) involves the following assumptions: i) (I-β) 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 becomes 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 a 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. [13,14,15] 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.

3.2. 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. [16,17,18,19]

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. [16,17,18,19] 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.

4. Sources of Data and Variable Definitions

Availability of data is crucial to modelling the interaction between human activities and the environment. In the absence of sound data, proxies or indicators could be utilized. For example, emissions of SO_2 and NO_x could serve as indicators of air pollution.

Sulfur dioxide interacts in the atmosphere to form sulfate aerosols, which may be transported long distances through the air. Most sulfate aerosols are particles that can be inhaled. Higher levels of sulfate aerosols are associated with increased morbidity (sickness) and mortality from lung disorders, such as asthma and bronchitis. Decreases in nitrogen oxide emissions are also expected to have a beneficial impact on health by reducing the nitrate component of inhalable particulates and reducing the nitrogen oxides available to react with volatile organic compounds and form ozone. Ozone impacts on human health include a number of morbidity and mortality risks associated with lung disorders.[1,2,20]

Cumulative effects of pollutants such as SO_2, NO_x, VOCs, etc., on humans include emphysema, respiratory tract irritation from gas and particles, asthma, heart trouble, lung cancer, irritation, etc. Expenditure to protect humans from emissions of NO_x, SO_2, VOCs, CO and CO_2 has been increasing. For example, in the USA, it is estimated that air pollution costs $150 billion yearly in health care: $100 billion from indoor air pollution and $40 billion from automobiles.[20]

Time series data on socioeconomic, environmental, and human heath are difficult to gather. Even when available, the units of measurements may not be the same. Fortunately the OECD has compiled, though deficient, a large amount of health-related data that served as the primary source for this study.[21]

The data were divided into four categories: i) North America (Canada and USA), ii) the Pacific-Rim (Japan, Australia, and New Zealand), iii) Europe (UK, Ireland, Spain, Portugal, France, Italy, Germany, Switzerland, Austria, Denmark, Norway, Belgium, the Netherlands, Finland and Sweden), and iv) all OECD countries. The criteria for grouping of countries are geographical proximity.

Several variables were examined in undertaking this study. Many variables were discarded due to lack of data and 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, environmental and human health variables.

The variables considered in the present study includes: Mortality from all causes measured in deaths /100 00 (MOALL); potential year life lost, except suicide, number per 100 000 (LIFELO); incidences of cancer per 100 000 population (CANC); national health expenditure in % GDP (EXPEN); total costs for all ICD categories in millions of dollars (CICD); total costs due to respiratory system disorder in millions of dollars (CICDR); total costs due to circulatory system disorder in millions of dollars (CICDC); medical care coverage in % population(COVER); calories intake (in number/capita/day) (CALO); protein intake(in grams /capita/day) (PROT); fats & oil (in kilo /capita) (FAOIL); fruits and vegetables (kilo/capita (FRUVEG); fibers (kilos/capita kilos) (FIBRE); population in number (POPU); total employment in % total population (EMPLO); GDP in million US$(GDP); labour productivity (GDP/labour productivity gain) (LABPRO); total factor productivity (GDP/ factor productivity gain) (TFP); enrolment in secondary and above schools in persons (EDUCA); emissions of NO_x, SOx, VOCs, CO_2, and CO in thousands of tonnes; and energy consumption in tonnes of oil equivalent (ENERY). Due to lack of statistical convergence, indices were derived for food intake and emissions were aggregated into two groups.

Emissions of pollutants such as NO_x, SO_2, and VOCs (labeled as NOSOVO) were summed to capture the joint impact on human health as well as to reduce the number of parameters. Similarly, emissions of CO_2 and CO were combined, and labeled as (TOCOCO2). The food intake indices was derived as follows:

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

Where F refers to intake of food, i indicate the food type (protein, fats/oil, fiber, calories, fruit and vegetables); r to country and t refers to years. The formula indicates that the food intake of a given region in any year is approximately equal to the ratio of intake of a particular type of food to the maximum intake of the same food in any given year summed over five food groups. Thus, its value is truncated between zero and five. The higher the values of this index the higher and/or more “balanced” the food intake of a certain region is.

The variables used in this study could be divided into two groups: endogenous and exogenous. The endogenous variables are health coverage; food index; emissions of NO_x, SO_2, and VOCs; education; mortality; incidences of cancer; labour productivity; expenditure for health; emissions of CO and CO_2; life lost; and total factor productivity. The observed exogenous variables are GDP; population; employment and energy consumption.

5. Results of LISREL analysis

The Results of LISREL analysis for OECD, Europe, North America and Pacific-Rim are presented in Table 1. For some of the causal linkages indicated in figure 1, estimates could not be derived due to statistical problems such as lack of convergence.

Prior to analysis of causal relationships, Pearson's correlation analysis, using a two-tailed test, was conducted. The results indicated that mortality is positively and significantly associated with emissions, and health expenditure is significantly associated with all mortality, life lost, incidences of cancer, and emission of pollutants. Interestingly, growth in the overall economy is negatively associated with mortality but positively with incidences of cancer and other forms of illness. Emissions of pollutants (NO_x, SO_2, VOCs, CO and CO_2) as well consumption of energy is positively and significantly associated with most variables included in the present study. A quick summary of the results of the Pearson's correlation analysis indicated that i) economic growth and other exogenous factors such as energy consumption and population are positively and significantly correlated with pollution levels, and that ii) emissions of pollutants are positively and significantly correlated with human health indicators as well as expenditures on human health.

Increases in health coverage and education contribute to reduced incidences of cancer. Emissions of pollutants such as SO_2, NO_x, VOCS, CO and CO_2 contribute significantly to increased incidences of cancer. On the other hand employment and economic growth significantly and positively influence health coverage while they are negatively affected by increases in population.

The level of employment and growth in the economy (GDP) positively and significantly influences the level of education. As indicated in the paper, combating the impacts of pollutants or environmental degradation on human health costs a substantial amount of money. The result of the analysis indicated that incidencesof cancer, life lost and mortality from all causes significantly and positively contributed to increases in expenditure on health. On the other hand, improvements in labour and total factor productivity help reduce spending on health.

One of the socioeconomic factors included in this study was an index for consumption of food. The result indicates that the level of employment and economic growth contribute to increases in "balanced" food consumption. Food consumption in turn contributes to increases in labour productivity, reduced life lost, and reduced mortality.

Health coverage, education, and productivity of other production inputs positively and significantly influence the productivity of labour. Incidences of cancer, mortality, and emissions of SO_2, NO_x, VOCS, CO and CO_2 positively influence life lost. However, life lost could be minimized by increases in education, labour productivity and "balanced" food consumption.

Incidences of cancer and emissions of the pollutants positively influence mortality from all causes. However, increases in health coverage, education, and "balanced" food contribute to reduced mortality. On the other hand, energy consumption, economic growth, and population significantly influenced emissions of the pollutants of concern. Improvements in productivity were positively influenced by education and but negatively by emissions of pollutants.

The findings for Europe, North America and the Pacific- Rim seem to confirm the results for the OECD. However, due to lack of statistical convergence, some of the causal linkages were eliminated from the analyses for these three economic regions (see Table 1).

In summary, the findings of the LISREL analysis show that investments in education, increased employment, reduced emissions of pollutants and increased health coverage will contribute to i) reduced the incidencesof cancer and mortality, ii) increased labour and total factor productivity, hence economic growth, and iii) reduced life lost. Furthermore, educating the public about the usefulness of a “balanced” diet may contribute to increases in productivity, reduce life lost and mortality. In general, it seems that intervention strategies that are intended to i) improve the education and availability of food, and ii) protect the environment from increased pollution will makeup the principal driving forces for improvements in environmental quality and human health.

6. Conclusions and Recommendations

Human activities are the driving forces for increased consumption of energy and other resources. The extraction or use of resources results in a significant amount of wastes and emissions. These unwanted products will find their way into the environment as the primary sink. Thus the environment provides goods and services or factors of production, at the same time serves as storehouse of unwanted products.

Economic growth is often accompanied by accelerated industrialization. The primary driver of industrialization has always been consumption of energy. Emissions and wastes resulting from energy consumption and extraction of other resources make up a significant portion of human and environmental risk factors. These risk factors pose threats by causing illness, reduced productivity, mortality, morbidity, etc. Investments and/or improvements with respect to parameters such as education, “balanced” diet and social policies such as health coverage could ameliorate the effects of environmental risk factors. Nevertheless, the speed with which wastes and pollution are generated is faster than what the environment can assimilate. Therefore, governments are spending a significant amount of scarce financial resources to protect human health and the environment. However, strategies that attempt to minimize impacts or effects cannot be sustained for a long time.

National and international agencies and countries should implement strategies to influence forces that accelerated depletion of resources and degradation of the environment. Without a concerted effort by all countries, the impacts of trade on accelerated extraction of resources, and industrialization on emission of transboundary pollutants, etc. would increase causing more threats to humans and the environment at regional, country and continental levels. The findings of the present study confirmed that i) exogenous factors such as economic growth, population and energy consumption contribute to increased emissions of pollutants, and ii) that these pollutants, directly or indirectly, contribute to increased mortality, incidences of cancer, life lost, and loss in productivity, and iii) the combined effects of (i) and (ii) on environmental degradation is that an ever increasing amount of money has to be devoted on health care system. Obviously, this pattern of progress or performance of countries cannot be sustained for an indefinite future. Policies that aim to implement strategies that would anticipate and prevent environmental and human health risk factors should be implemented to ensure progress toward sustainable environment and development.

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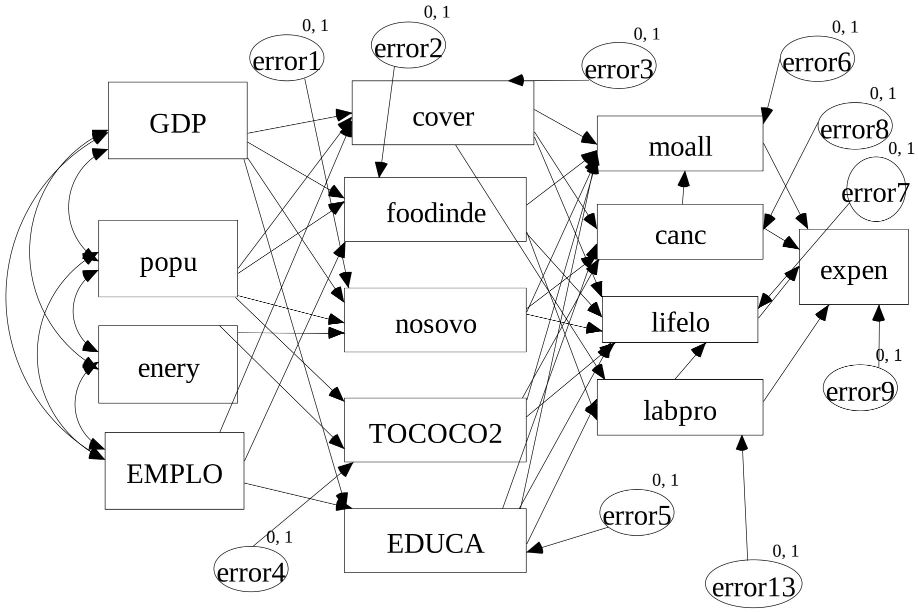
Fig. 1. General Model of Casual Linkages and Interrelationships Between Socioeconomic, Environmental and Human health Variables



ACRONYMS used in the model

MOALL- Mortality from all causes;
LIFELO- Potential year life lost, except suicide;
CANC- Incidencesof cancer per 100 000 population;
EXPEN-National health expenditure in % GDP;
CICD- Total costs for all ICD categories;
CICDR-Total costs due to respiratory system disorder;
CICDC- Total costs due to circulatory system disorder;
COVER- Medical care coverage in % population;
FOODINDE- Food Index for calorie, fats & oil, fruits and vegetables, protein, and fibers
POPU- Population in number (POPU);
EMPLO-Total employment in % total population;
GDP- Gross Domestic product;
LABPRO-Labour productivity;
TFP- Total factor productivity;
EDUCA- Enrolment in secondary and above schools;
NOSOVO- Sum of emissions of NO_x, SOx, and VOCs;
TOCOCO2- Sum of CO_2 and CO; and
ENERY- Energy consumption.

Table 1. Results of LISREL Analysis by Country Group, Based on data from 1980 to 1997

Category	OECD		Europe		North America		Pacific-Rim	
Direction of Causality	Estimate	C.R.	Estimate	C.R.	Estimate	C.R.	Estimate	C.R.
canc <----------- cover	-1.6820	-5.3070	0.453	1.502	-1.838	-6.23		
canc <----------- EDUCA	-0.9000	-7.3960	0.589	4.28	1.213	21.865	1.132	7.537
canc <---------- nosovo	2.0020	6.9860	2.001	5.502	1.002	12.935	1.003	9.536
canc <--------- TOCOCO2	1.0130	9.6150	1.02	2.278	1.049	9.935	0.83	9.925
cover <---------- EMPLO	2.2460	9.4100	0.227	5.882	1.039	7.024	1.914	10.156
cover <------------ GDP	1.9600	8.7460	0.872	8.891	1.98	16.428	2.583	14.543
cover <----------- popu	-1.2000	-10.7930	-1.08	-18.895	-2.09	-23.375		
EDUCA <---------- EMPLO	7.0000	17.8130	4.033	9.196	1.89	10.165		
EDUCA <------------ GDP	2.1500	26.3740	4.241	13.236	2.417	15.942		
expen <----------- canc	2.0020	6.5280	2.101	9.125	1.058	8.582	2.119	16.951
expen <--------- labpro	1.0200	3.3840	-0.459	4.35	-0.003	-5.03	-0.598	-11.461
expen <--------- lifelo	2.0010	18.0870	-0.0023	-2.017	1.019	5.391	3.701	14.35
expen <---------- moall	3.0190	22.2170	3.001	16.737				
expen <------------ tfp	-0.9770	-8.9600						
foodinde <------- EMPLO	3.0110	13.3890	2.106	8.275	1.021	5.563	1.782	11.706
foodinde <--------- GDP	4.5000	13.8970	2.45	18.307	1.029	14.692	1.987	9.404
foodinde <-------- popu	-2.4000	-12.1230	-1.001	8.308	-0.982	-13.258	-0.996	-15.587
labpro <--------- cover	4.6000	11.2240	2.527	6.687	0.421	6.157		
labpro <--------- EDUCA	3.8250	9.2330	1.452	11.558	2.006	16.433	3.03	19.704
labpro <------ foodinde	6.2000	9.1860	3.68	4.663	2.202	5.042	4.758	9.569
labpro <----------- tfp	1.0960	7.2300						
lifelo <---------- canc	3.2650	3.4560						
lifelo <--------- cover	1.8970	12.7370	1.429	5.805				
lifelo <--------- EDUCA	-0.8010	-5.9290	1.093	12.723				
lifelo <------ foodinde	1.8330	5.0510	0.934	4.781				
lifelo <-------- labpro	0.9830	-9.2090	0.001	0.558				
lifelo <--------- moall	5.9050	47.7730						
lifelo <-------- nosovo	-0.0780	-10.1930	0.022	0.966				
lifelo <------- TOCOCO2	-2.3990	-13.7410	0.859	4.888				
lifelo <---------- canc	3.265	5.456	3.193	11.02	0.797	2.341	1.066	7.607
moall <---------- cover	-2.7800	-9.3230	0.875	4.039	-0.973	-7.437		
moall <---------- EDUCA	-1.2000	-16.0800	0.398	2.869	0.992	3.887	0.774	5.538
moall <------- foodinde	-2.5240	-8.4240	0.322	2.092	-1.08	-2.019	1.054	4.682
moall <--------- nosovo	1.0070	10.4360	0.501	4.319	0.349	2.526	3.901	13.334
moall <-------- TOCOCO2	1.0650	12.9280	1.039	7.941	1.013	3.545	0.154	9.544
nosovo <--------- enery	1.9290	26.1290	1.191	17.903	1.042	16.89	0.73	4.631
nosovo <----------- GDP	-2.0020	-8.7400	3.001	11.262	2.006	6.219	0.307	5.179
nosovo <---------- popu	3.0510	15.1650	2.022	8.135	1.257	12.764	2.004	11.228
nosovo <------- TOCOCO2	-2.4210	-0.9720						
tfp <------------ EDUCA	1.0070	11.7630						
tfp <----------- labpro	2.0040	21.3480						
tfp <----------- nosovo	-3.0630	-14.0520						
tfp <---------- TOCOCO2	-3.7510	-9.7380						
TOCOCO2 <-------- enery	4.0200	15.5000	2.005	14.345	3.043	19.541	0.221	7.176
TOCOCO2 <------- nosovo	0.0210	1.0180						
TOCOCO2 <--------- popu	3.9000	9.2920	3.001	7.732	2.003	15.276	2.605	12.31