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ABSTRACT

Several studies have shown the environmental and health impacts of emission of criteria air pollutants such as SO_2, NOx, PM, and VOCs. These pollutants are primarily associated with acid rain, ground level ozone or smog, and formation of inhalable particulate. The present study will examine trends in emissions of these pollutants, and selected indicators of human health affected by these pollutants over the past two decades. Furthermore, the study will implement a method called linear structural relationship or causal analysis to identify the impact of factors that may affect ambient concentration of pollutants and the human health. Finally, the study will determine whether or not the changes observed over the past two decades with respect to reduction in emissions, improvements in human health indicators, and environmental expenditures are statistically significant. The study is expected to make contribution towards identification of factors or issues that policy makers and regulators should focus on and whether or not regulations have made significant difference in influencing emissions, environmental and human health risk factors.

Key Words: LISREL, Path, Causal, Emissions, Environmental, Health, Time-series, Econometrics, Chow

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1. INTRODUCTION

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] But behavioral changes with respect to activities that create or intensify environmental and human health risks may prove important in the design of regulations.

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 goods and services. However, 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 in influencing behavior of individuals. This may be due to market imperfections, institutional, social, political and other 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 or decision-making of individuals that impact environmental and human health risks is education. One way of educating the public is to make information available about 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 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.

The purpose of this study is to examine causal linkages and interrelationships between selected socioeconomic, environmental and human health-related 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 and human health, ii) provide empirical evidence that would allow identification of important variables for inclusion in national environmental and human health programs and policies. Factors that were found to influence environmental and human health could be targeted by regulation in order to increase success in reducing pollution.

2. ENVIRONMENTAL REGULATIONS, HUMAN HEALTH AND TRENDS IN EMISSIONS OF CRITERIA AIR POLLUTANTS

The purpose of this section is to identify selected or relevant environmental, human health and related regulations that may have played a vital role in reducing pollution, thus their impacts on human health. Furthermore, the section intends to infer whether or not regulations have been successful in achieving the goal of reducing emissions, and if not suggest alternative emission reduction strategies.

To ensure the purity of certain foods and drugs, the Food and Drug Administration was enunciated in 1931. In 1938, the role of the Food and Drug Administration (FDA) was expanded to include prevention of harm to consumers. [12,13]

In 1970, the Environmental Protection Agency (EPA) was created to consolidate and expand environmental programs. Its regulatory authority was expanded through the Clean Air Act (1970), the Clean Water Act (1972), the Safe Drinking Water Act (1974), the Toxic Substances Control Act (1976), and the Resource Conservation and Recovery Act (1976). [12,13]

In the 1970s, the Federal Government attempted to address the problems of the dwindling supply and the rising costs of energy. In 1973, the Federal Energy Administration (FEA) was directed to manage short-term fuel shortage. Less than a year later, the Atomic Energy Commission was divided into the Energy Research and Development Administration (ERDA) and an independent Nuclear Regulatory Commission (NRC). In 1977, the FEA, ERDA, the Federal Power Commission, and a number of other energy program responsibilities were merged into the Department of Energy (DOE) and the independent Federal Energy Regulatory Commission (FERC). [12,13]

Successful air-pollution policy must reduce the emissions of harmful pollutants. For decades, environmentalists, the EPA, and others have waged a battle over the designation of "hazardous" air pollutants. However, most policy attention has been given to the "criteria" pollutants such as ozone (O3), oxides of nitrogen (NOx), carbon monoxide (CO), sulfur oxides (SOx), particulate matter (PM), and lead (Pb).

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Due to efforts, programs and policies of regulatory agencies, significant progress has been made on the environmental front over the past two-and-a-half decades. Emissions of every major air pollutant have decreased (with the exception of nitrogen oxides). Major bodies of water once considered dead now support fish populations. Current waste disposal and treatment methods are far advanced from earlier practices.

Estimates of the actual effects of regulations on air quality depend on accuracy of the estimates of emissions reductions. However, data on emissions of pollutant is not consistent due to the enormous number of sources of pollutants. Furthermore, consistent data are lacking because environmental policy generally has been enforced through technology-based standards, not precise emissions standards. If air-pollution policy were affected through pollution taxes, for example, much better emissions data would surely be available today. The precise calculations of the effect of emissions on air quality differ depending on the pollutants studied. In situations where data become available, variability of meteorological conditions and atmospheric chemistry may affect the relationship between emissions reduction and ambient concentration, thus in assessing the impact on human and environmental health.

The effects of various pollutants on health at differing exposure levels are even more difficult to measure. Determining the relationship between exposure data and observed mortality and morbidity rates is very complex, because it is difficult to know and account for other potential causative agents to which people might have been exposed. In general, the assessments of the impacts of environmental or human health are developed by combining three kinds of information: (1) statistical estimates of the incremental effect of a unit change in emissions or ambient concentrations; (2) the expected decreases in emissions or concentrations; and (3) data on the prevailing level of the effect or the size of the affected population.

The strongest correlations between morbidity and ambient concentration of particulate matter have been detected for elderly people with preexisting chronic cardiovascular and respiratory disease. The principal causes of death are chronic obstructive pulmonary disease (COPD), pneumonia, cardiovascular disease, and stroke. Furthermore, epidemiological study shows statistically significant correlations between annual particulate matter levels and mortality risk ratios that have been adjusted for age, gender, body mass, education, smoking behavior, alcohol consumption, and occupational exposures to several specific hazardous substances. [1,2,3,4,5,6,7,8,9,10,11,13]

Meteorological conditions directly affect the air-exchange rates. That is, the rate at which indoor air is replaced by outdoor air within structures. When a change in meteorological conditions (e.g., a decline in wind velocity or a thermal inversion) causes air movement to decrease, air-exchange rates decrease; and conversely. When air-exchange rates decrease, the infiltration of airborne substances from outdoor to indoor air and the exfiltration of airborne substances from indoor to outdoor air decrease. Thus, when a change in meteorological conditions causes the ambient concentrations of particulate matter and other substances to increase in the outdoor air, the concentrations of airborne substances in the indoor air will increase concurrently and will contain an increased proportion of substances emitted from indoor sources. The ambient concentrations of substances in the outdoor and indoor air therefore will be systematically correlated due to their mutual dependence on meteorological conditions. Thus, differences in annual volumes of pollutant emissions account for only a minor portion of measured variations in annual average pollutant concentrations among areas and over time. [1,2,3,4,5,6,7,8,9,10,11,13]

Progress in reducing pollution took place simultaneously with major growth in population and in the economy. From 1970 to 1996, population, GDP and vehicle miles traveled grew by 29%, 104%, and 121% respectively. The cost of environmental protection from 1971 to 2000 was estimated to be about $3.5 trillion (in 1995 dollars), while the cost of complying with environmental regulations was $198 billion in 1997. [12,13]

A study by USEPA indicated that approximately 90 percent of the Clean Air Act’s estimated benefits of $23 trillion are attributed to reductions in mortality and morbidity associated with lowered ambient concentrations of particulate matter. Much smaller benefits are estimated for decreases in morbidity attributed to reduced emissions of pollutants such as O_3, SO_2, NO_2, and CO, individually or in combination.[12,13]

3. METHODOLOGY

3.1. Introduction

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.12,13,14 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. 12,13,14

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. 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. Furthermore, the study will make use of econometric time series models.

3.2. The Empirical Model

Linear Structural Equation Models (LISREL) have been used in several areas of the social and behavioral sciences.[15] 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. [15] 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:

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

where η and ζ are vectors of latent dependent and independent variables, β (mxm) and Γ (mxn) are coefficient matrices and $\varepsilon = (\varepsilon_1, ..., \varepsilon_m)$ 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 0-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

$$Y = \Omega_y\eta + \upsilon \qquad \text{.......................} (2)$$

$$X = \Omega_x\zeta + \delta \qquad \text{.......................} (3)$$

Where υ 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.

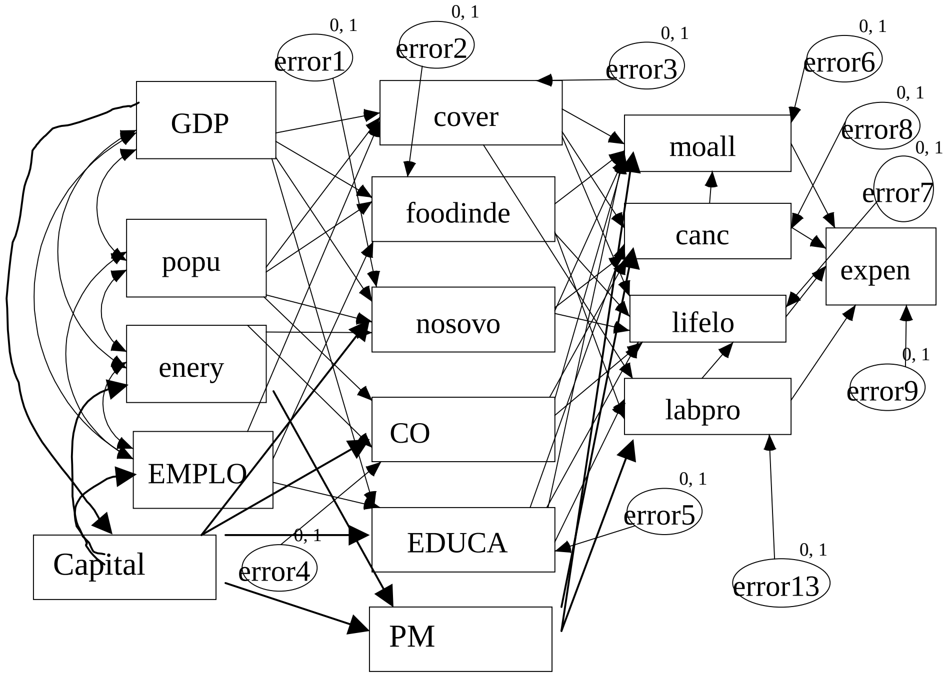
The full LISREL model is defined by the following three equations:

Structural Equation Model: $\eta = \beta\eta + \Gamma\zeta + \varepsilon$ .... (4)

Measurement Model for Y: $Y = \Omega_y\eta + \upsilon$ .... (5)

Measurement Model for X: $X = \Omega_x\zeta + \delta$ .... (6)

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- Incidences of 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;
Capital- Fixed capital formation;
LABPRO-Labor productivity;
TFP- Total factor productivity;
EDUCA- Enrolment in secondary and above schools;
NOSOVO- Sum of emissions of NO_x, SOx, and VOCs;
PM- Emissions of PM
CO- Emissions CO; and
ENERY- Energy consumption.

These equations assume that ζ and ε, η and υ, ζ and δ are uncorrelated, ε, υ and δ are mutually uncorrelated and that β has zeros in the diagonal and $\mathrm{I}-\beta$ is non-singular.[15]

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.[15] The data set examined in this study contains only observed variables and assumed zero measurement error.

Thus, the LISREL model can be formulated as:

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

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 $\Phi = \text{cov}(\varepsilon)$. Equation (7) involves the following assumptions: i) $(\mathrm{I}-\beta)$ is non-singular, ii) $E(\varepsilon)=0$ where E is the expected value operator, and iii) ε is uncorrelated with x. If the covariance or correlation matrix is analyzed ∀ may be omitted. Solving for y will give the following equation:

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

Where $A = (\mathrm{I}-\beta)^{-1}$. For β =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.[15,16,17,18,19,20] 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.

3.3. Econometric Time Series Model

Econometrics time-series analyses are not widely used in the estimation and forecasting of time-series environmental or natural resource variables. The literature on these models such as moving averages(MA), autoregressive(AR), autoregressive moving averages (ARMA), and autoregressive integrated moving averages(ARIMA) models is extensive. 21,22,23,24,25,26 The choice of a model to forecast a series is based on selected measures of fit.

In time series primary economic data (such as investment) or environmental data (such as emissions), the forces that generate the series may keep them together so that they would not drift apart. If a series is drifting apart, stationarity can be achieved by applying various methods. It is essential to establish stationarity if the purpose is to examine true trends in the series and if there is a need to undertake forecasting.

In forecasting future values of a variable, time-series analysis relates the current values with past values, and current and past random disturbances. The unique feature of time-series analysis is that it doesn't begin with any conceptual framework provided say by economic theory. Instead, emphasis is placed on making use of information in the past values of a variable to forecast its future value.

There are several estimating and forecasting techniques of time-series variables. Many of these techniques are fitted to a data on the assumption that the model is an adequate approximation to the true generating mechanisms and then forecasts are made using the model. Among most widely used models to forecast time series data, the ARIMA has been found to be superior.22,23

In addition to AR and MA process, ARIMA models have integrated series. If one of the purposes of using these models is forecasting, it is imperative to determine whether or not the series is stationary. Non-stationary series could be transformed such as by differencing so that the series could be made stationary. The number of times a series is differenced to be stationary indicates the order of integration. All the data used in this study will be tested for stationarity (unit-root) before implementing forecasts.

ARIMA is a model that incorporates both autoregressive (order p) and moving average (order q) processes. If $W_t = \Delta^d Y_t$, and W_t is an ARMA(p,q) process, then Y_t is an integrated (order d) autoregressive moving average process of order (p,d,q). ARIMA(p,d,q) can be written, using a backward shift operator, as:

$$\phi(\mathrm{B})\Delta^d Y_t = \delta + \theta(\mathrm{B})\varepsilon_t) \qquad \ldots\ldots\ldots\ldots\ldots\ldots \quad (9)$$

With $\phi(\mathrm{B}) = 1 - \phi_1\mathrm{B} - \phi_2\mathrm{B}^2 - \ldots\ldots\ldots - \phi_p\mathrm{B}^p$

$$\phi(\mathrm{B}) = 1 - \phi_1\mathrm{B} - \phi_2\mathrm{B}^2 - \ldots\ldots\ldots - \phi_p\mathrm{B}^p \qquad \ldots\ldots\ldots\ldots\ldots\ldots \ (10)$$

$\phi(\mathrm{B})$ is called the autoregressive operator and $\theta(\mathrm{B})$ the moving average operator.

3.4. Structural Change

In addition to examining trends using time-series models described above, the study will also examine shifts in the structure of selected macro economic, environmental and human health related variables over a period of two decades to ascertain the impacts of regulations.

In developing the empirical model to conduct a structural change test, it is hypothesized that all coefficients including the error structure for a given period remains unchanged over time. [27] Let's assume that Y is the dependent variable and X's are the independent variables.

Consider the following unrestricted linear equations:

$$Y_i = \beta_1 + \beta_2 X_2 + \beta_3 X_3 + \ldots\ldots \beta_k X_k + \varepsilon i \qquad \ldots\ldots (11)$$
$$Y_j = \alpha_1 + \alpha_2 X_2 + \alpha_3 X_3 + \ldots\ldots \alpha_k X_k + \varepsilon j \qquad \ldots\ldots (12)$$

Where i=, 1, ….N, and j=, 1, ..M.

Assuming that $\alpha_1=\beta_1$, $\alpha_2=\beta_2$,…. ,$\alpha_k=\beta_k$, equations 1 and 2 can be changed unrestricted equations given by:

$$Y_i = \beta_1 + \beta_2 X_2 + \beta_3 X_3 + \ldots\ldots \beta_k X_k + \varepsilon i \qquad \ldots\ldots (13)$$

If the structural change test is performed for a single time series variable, similar models for two periods can be constructed using an autoregressive model. The restricted form the equation can be given as:

$$Y_{it} = \beta_0 + \beta_1 Y_{t-1} + \beta_2 Y_{t-2} + \ldots\ldots \beta_k Y_{t-k} + \varepsilon_{it} \qquad \ldots\ldots (14)$$

In order to test whether or not there is a structural (also called chow-test) change, a test statistics should be derived as follows:

$$F = \frac{\left\{ RRSS - URSS \right\} / k}{\left\{ URSS \,/ \left(N + M - 2k \right) \right\}}$$

Where RRSS refers to restricted residual sum of squares, URSS (sum of residuals from equation 11 and 12) refers to unrestricted residual sum of squares, N is number of observations related to equation 11 and 12 respectively, and K is then number of parameters. The resulting test statistic is distributed F (k, N+M-2*k).

3.5. Sources of Data and Variable Definitions

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. The OECD has compiled, though deficient, a large amount of health-related data that served as the primary source for this study.[28]

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; potential year life lost, except suicide, number per 100 000; incidences of cancer per 100 000 population; health expenditure in million of dollars (total, hospital care, ambulatory, in-patient and drug), total costs for all ICD categories in millions of dollars; total costs due to respiratory system disorder in millions of dollars; total costs due to circulatory system disorder in millions of dollars; medical care coverage in % population; calories intake (number/capita/day); protein intake(grams /capita/day); fats & oil (kilo /capita); fruits and vegetables (kilo/capita); fibers (kilos/capita kilos); population in number; total employment in % total population; GDP in million US$; labor productivity (GDP/labor productivity gain); total factor productivity (GDP/factor productivity gain); enrolment in secondary and above schools in persons; emissions of NO_x, SOx, VOCs, PM and CO in thousands of tonnes; fixed capital stock, and energy consumption in Bbtus.

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, CO, PM and VOCs; education; mortality; incidences of cancer; labor productivity; expenditure for health; life lost; and total factor productivity. The observed exogenous variables are GDP; population; employment, fixed capital stock (in millions dollars), and energy consumption (in Bbtus).

4. RESULTS AND DISCUSSIONS

4.1. Results of Time Series Analysis

Prior to forecasting trends in emissions of criteria air contaminants, selected macro-economic and health-related variables, it is imperative to determine whether or not the series is stationary. That is, whether or not the data is characterized by constant variance. Review of literature indicates that the Augmented Dickey-Fuller (ADF) and Phillips-Perron tests are the two commonly used tests for stationarity or unit-root.[21,22,23,242,25] The present study utilized the ADF tests.

The results of unit root test indicated that all emissions, macroeconomic and health related variables exhibited non-stationery. However, after differencing, all the series exhibited stationarity. Once, stationarity was established, ARIMA models were fitted to produce a forecast for the period 1998 to 2020 (for emissions), and from 1994-2020 (for health-related variables).

From 1970 to 1998, emissions of NOx and PM continued to increase. However, emissions of CO, VOC and SO_2 declined (see Table 1). Overall, the reduction in emissions doesn't seem to be significant considering the fact that there have been several regulations that were passed since the 70's. Despite the regulatory efforts, it is possible to conclude that aggregate emission of criteria air contaminants have not changed significantly.

The major health related impacts originate from the formation of ground level ozone (smog). [12,13] NOx and VOCs are the precursors of smog. The contribution of these contaminants toward the formation of smog at various locations and mixing heights vary. Considering that there are relatively smaller sources of emission of VOCs in the USA, emissions of NOx may continue to dominate the formation of smog. The simple forecast produced in this study showed an increasing trend in emissions of NOx. However crude this forecast may be, the result seem to

Table 1. Results of Forecast of Selected Macro-Economic, Environmental & Health Related Variables

YEAR	1970	1975	1980	1985	1990	1995	2000	2005	2010	2015	2020
CO	0.00%	-10.13%	-9.72%	-10.45%	-21.42%	-27.11%	-29.08%	-26.70%	-24.72%	-23.06%	-21.68%
NOX	0.00%	6.13%	12.88%	10.84%	16.60%	20.83%	17.44%	15.37%	14.04%	13.19%	12.64%
VOCs	0.00%	-16.21%	-15.51%	-15.82%	-22.99%	-32.07%	-40.67%	-38.65%	-36.83%	-35.20%	-33.72%
PM10	0.00%	-42.25%	-46.03%	250.38%	237.54%	110.87%	148.59%	115.39%	99.73%	92.33%	88.85%
SO2	0.00%	-10.44%	-16.87%	-25.45%	-24.07%	-38.45%	-36.17%	-34.38%	-32.77%	-31.33%	-30.04%
Population	0.00%	5.33%	11.06%	16.30%	21.88%	28.36%	34.32%	40.16%	45.97%	51.76%	57.56%
Employm.	0.00%	9.11%	26.22%	36.18%	50.99%	59.06%	70.91%	82.64%	94.37%	106.10%	117.84%
Energy	0.00%	6.17%	15.59%	13.11%	23.96%	34.11%	38.16%	36.50%	34.99%	33.61%	32.35%
GDP	0.00%	57.15%	168.51%	301.25%	450.51%	596.62%	722.14%	840.11%	957.78%	1075.44%	1193.11%
Capital	0.00%	18.68%	39.19%	58.31%	80.03%	99.44%	119.35%	139.18%	159.01%	178.85%	198.68%
Calorie	0.00%	-1.26%	-1.23%	2.52%	5.04%	6.28%	7.52%	8.75%	9.99%	11.23%	12.47%
Protein	0.00%	-0.95%	-6.67%	0.00%	3.05%	3.82%	4.58%	5.35%	6.12%	6.89%	7.66%
Fat oil	0.00%	-38.10%	-42.86%	-61.90%	-69.04%	-86.28%	-103.52%	-120.76%	-138.00%	-155.23%	-172.47%
Fruit & Veg.	0.00%	15.11%	15.33%	21.65%	26.02%	29.48%	36.45%	42.16%	47.91%	53.66%	59.41%
Factor prod.	0.00%	4.12%	6.59%	12.82%	15.48%	19.18%	23.04%	26.89%	30.75%	34.60%	38.45%
Labor prod.	0.00%	6.90%	9.42%	18.72%	22.42%	28.03%	33.63%	39.23%	44.83%	50.42%	56.02%
DEBT	0.00%	9.09%	45.45%	122.73%	127.27%	101.72%	101.81%	111.32%	123.16%	135.58%	148.14%
Heath Cost	0.00%	78.48%	237.61%	485.34%	855.06%	1258.76%	1577.79%	1871.34%	2145.96%	2406.52%	2656.64%

point to the fact that there need to be either a change with respect to strategies aimed at reducing emissions NOx or increase the magnitude of reduction.

Emissions and deposition of SO_2 and NOx in the presence of water are the major causes for the formation of acid rain. The damages that acid rain causes to forests, fish, buildings, etc. are well documented. [29] These two precursors are also the major source of inhalable particulates that have been attributed as the major cause of several kinds of illness. The conclusion is that while some degree of success has been achieved with respect to reducing emissions of SO_2, a lot more has to be done with respect to emission of NOx. Considering the fact that either of these pollutants contributes to acid rain, eutrophication and formation of particulates, it is necessary to find ways of further reduction emissions of NOx and SO_2. The fact that emissions of SO_2 is declining while emissions of NOx is rising over the next 20 years may indicate that the problem of acid rain as well as the formation of inhalable particulates of nitrogen may continue to be an environmental and human health concern.

Forecasts of mortality rates showed a slight decline. Health care expenditures (public health care costs, inpatient, and ambulatory expenses) showed significant increases. Consumption of food continued to show an upward trend. Selected measures of economic growth such as employment, fixed capital stock, GDP, total factor and labor productivity all showed an increasing trend.

The results of these univariate forecasts emphasize one important issue: that the economy is growing; that people are employed and their productivity is increasing; that despite increases in regulatory costs emissions are increasing, so are health care expenditure. In order reduce health care costs, improve environmental and human health, it is important to influence rate growth of emissions and/or patterns of growth in components of the overall economy that determine the nature and magnitude of emissions of criteria air contaminants.

The time-series models used in this study rely only on past values of selected variables. There could be over or under estimations. However, they are informative because they provide a ballpark figure with respect to what may happen if status quo (or do nothing scenario) prevails.

4.2. Structural Change Tests

The results of structural change tests are presented in Table 2. The tests were performed by dividing the series into two groups: 1970-1983 and 1984-1998 (for air emissions). In order to test shifts with respect to variables related to selected macroeconomic and health indicators, the data was divided into 1970-1981 and 1982-1994. The estimates of structural change tests indicated that emissions of particulates, total factor productivity, GDP, consumption food, and labor productivity showed a positive and significant structural change. Furthermore, total healthcare expenses, public health care, inpatient expense, and ambulatory expense have all showed positive and significant changes. Mortality from all sources, however, showed reduction in growth rates but not statistically significant. It means, despite substantial spending in regulating emission of criteria air pollutants, the impact measured, as reduced emissions did not show statistically significant reductions. Consequently, there have been statistically significant shifts in impacts of emissions reflected by selected environmental and human health parameters.

Table 2. Results of Structural Change Test for Selected Variables

Variable	F-Ratio
CO	0.30
NOX	2.39
VOC	-0.40
PM10	5.196**
SO2	-0.47
EMPLOYMENT	2.01
GDP	4.82**
TFP	5.142**
Mortality	-0.34
Total health expense	4.48**
Public health expense	4.648**
Inpatient expense	5.3**
Ambulatory expense	4.7**
Pharmacy expense	2.37
Food Consumption Index	8.01**
Labor Productivity	4.60*

**, and * indicate Significant at 5% and 1% respectively.

4.3. Results of LISREL Analysis

The Results of causal (LISREL) analysis are presented in Table 3. For some of the variables, causal linkages indicated in figure 1 could not be estimated due to statistical problems such as lack of convergence.

A two-tailed Pearson's correlation analysis was conducted prior to performing analysis of causal relationships. The results of the analysis showed that that mortality is positively and significantly associated with emissions, and health expenditure is significantly associated with mortality from all sources, 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. This result may indicate the fact that people are able to extend their life due to improvements in health care, thus undermining the indirect linkage between growth in the economy, emissions and mortality. Emissions of criteria are contaminants such as NO_x, SO_2, VOCs, PM, and CO, and consumption of energy are positively and significantly associated with most variables included in the present study.

The results of correlation analysis showed that exogenous factors such as economic growth (GDP), total factor productivity, capital stock, energy consumption and population are positively and significantly correlated with emission of air contaminants. However, emissions of criteria air pollutants are positively and significantly correlated with human health indicators as well as expenditures on human health. The later is negatively related to labor and total factor productivity. That is, increases in productivity could help lower health care costs.

Economic growth (GDP) and employment are positively related to health coverage. These same factors also contribute to increase in education. The results of the study also showed that increases in health coverage and education may contribute to reduced incidences of cancer. However, emissions of pollutants will also significantly and positively contribute towards increased incidences of cancer.

The major debate in the regulatory arena is whether or not regulation is working or effective. This is because the cost of regulation (cost of administering and cost of complying) to minimize the impacts of pollutants on human and environmental health has shown significant increases over the past twenty years. The results of this study showed that incidences of cancer, life lost and mortality from all causes significantly and positively contributed to increases in expenditure on health.

The study included an index for consumption of food (fiber, fat, protein, and calories). The result of the analysis indicates that the level of employment and economic growth contribute to increases in "balanced" food consumption. The latter also contributes to increases in labor productivity, reduced life lost, and reduced mortality.

Table 3. Results of Linear Structural Relations Analysis

Category	Estimates	
Direction of Causality	Coefficient	C.R.
Cancer<------------ Cover	-1.6820	-5.3070
Cancer <----------- EDUCA	-0.9000	-7.3960
Cancer <----------- NOSOVO	2.0020	6.9860
Cancer <----------- CO	1.0130	9.6150
Cover <------------ EMPLO	2.2460	9.4100
Cover <------------ GDP	1.9600	8.7460
Cover <------------ POPU	-1.2000	-10.7930
EDUCA <--------- EMPLO	7.0000	17.8130
EDUCA <--------- GDP	2.1500	26.3740
Expenditure <----- Cancer	2.0020	6.5280
Expenditure <----- Labpro	1.0200	3.3840
Expenditure <----- Lifelong	2.0010	18.0870
Expenditure <----- Mortality-all	3.0190	22.2170
Expenditure <---- TFP	-0.9770	-8.9600
Foodindex <------- EMPLO	3.0110	13.3890
Food index <------- GDP	4.5000	13.8970
Food index <------- POPU	-2.4000	-12.1230
Labpro <------------ Cover	4.6000	11.2240
Labpro <----------- EDUCA	3.8250	9.2330
Labpro <----------- Food index	6.2000	9.1860
Labpro <----------- TFP	1.0960	7.2300
Lifelong <-----------Cancer	3.2650	3.4560
Lifelong <---------- Cover	1.8970	12.7370
Lifelong <---------- EDUCA	-0.8010	-5.9290
Lifelong <---------- Food index	1.8330	5.0510
Lifelong <---------- Labpro	0.9830	-9.2090
Lifelong <---------- Mortality-all	5.9050	47.7730
Lifelong <---------- NOSOVO	-0.0780	-10.1930
Lifelong <---------- CO	-2.3990	-13.7410
Lifelong <---------- Cancer	3.265	5.456
Mortality-all <----- Cover	-2.7800	-9.3230
Mortality-all <----- EDUCA	-1.2000	-16.0800
Mortality-all <----- Food index	-2.5240	-8.4240
Mortality-all <----- NOSOVO	1.0070	10.4360
Mortality-all <----- CO	1.0650	12.9280
NOSOVO <------- Energy	1.9290	26.1290
NOSOVO <------- Capita	-2.0020	-8.7400
NOSOVO <------- POPU	3.0510	15.1650
NOSOVO <------- CO	-2.4210	-0.9720
TFP <-------------- EDUCA	1.0070	11.7630
TFP <-------------- Labpro	2.0040	21.3480
TFP <-------------- NOSOVO	-3.0630	-14.0520
TFP <-------------- CO	-3.7510	-9.7380
CO <--------------- Energy	4.0200	15.5000
CO <-------------- NOSOVO	0.0210	1.0180
CO <------------- POPU	3.9000	9.2920

Education and health coverage contribute to improvements in productivity of labor. Life lost is positively associated with incidences of cancer, mortality, and emissions of pollutants. Life lost, however, can be minimized by improvements in education, labor productivity and food consumption.

The conclusion from this study indicates that investments in education, health coverage or health expenditure, employment, energy consumption, and capital formation, and reduced emissions of pollutants will contribute to i) reduced the incidences of cancer and mortality, ii) increased labor and total factor productivity, hence economic growth, and iii) reduced life lost. The study believes that there are two avenues towards ensuring that regulation becomes effective and that the results are sustainable. These are i) changing the mixes of regulatory framework (top-bottom or bottom-up) so that the costs justify the benefits; and ii) ensure that every decision maker (policy maker, corporate executive or household) is educated about the usefulness of a "balanced" diet and healthy environment, and how it may contribute to increases in productivity, reduce life lost and mortality. Focused and targeted interventions, such as those 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.

5. CONCLUSION AND RECOMMENDATIONS

Environmental and energy-related regulations are designed to influence human activities that are the driving forces for increased consumption of energy and other resources. Unsustainable extraction of energy, inefficient production processes, extensive use-of fossil fuel, etc. results in emission of pollutants that threatens environmental and human health. If environmental and human health risks persist, the paradigm of sustainable environment and development becomes wishful thinking or just a dream.

Curbing economic growth or industrialization may not be the only solution because of difficulty in limiting human wants as well as ensuring collaboration across states and nations. Therefore, it is essential to start targeted intervention. This targeted intervention should aim at ways in which the public can be educated about potential environmental and human health risks. The public can strike a trade-off between the human health and higher income for the present and future generation. One way of educating the public is by making evidence about the cause and effect of their own activities, ways in which they could become active participants to ensure that the risk are minimized.

The finding of this study indicated that GDP, energy consumption, employment, capital stock, emissions, and health care costs are growing. The threats to environmental and human health are becoming greater. The speed with which wastes and pollution are generated is faster than what the environment can assimilate. Increased government spending to protect human health and the environment or to the impacts of pollution cannot be sustained for a long time. The result from this study suggest that 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.

The findings of this study indicated 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 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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