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Global warming, air pollution and hedonic method

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Abstract
Global warming is increasingly becoming a threat to this planet. There is an urgent need to tackle this issue. Air Pollution has been identified as a foremost reason behind this. Global warming is directly proportional to Air Pollution. This paper presents a relationship between Global Warming and Air Pollution, need for environment evaluation and Hedonic Method which has been used by Mathematicians and Economists to address problem of Air Pollution. Various functional forms and way to implement hedonic method have been discussed.

Keywords: Parental attitude, participation, sports, girls

Introduction

1. Global Warming

Global Warming is the increase of Earth's average surface temperature due to effect of greenhouse gases, such as carbon dioxide emissions from burning fossil fuels or from deforestation, which trap heat that would otherwise escape from Earth. This is a type of *greenhouse effect*. Carbon dioxide and other air pollutants collecting in the atmosphere traps the sun's heat and cause the planet to warm up. Coal burning power plants are the biggest source of carbon dioxide pollution. Second comes automobiles. Global warming has been in effect since the mid-20th century. Since then, it is projected that with the current state of the environment, this increase will continue to happen. The United States Global Change Research Program (which includes the Department of Defense, NASA, National Science Foundation and other government agencies) has said that " global warming is unequivocal and primary human-induced". Global warming has affected climate change. The impacts of climate change have been felt in recent decades on all countries and across the oceans. The more human activities disrupt the climate, the greater the risk. Continued emissions of green house gases will result in further warming and long lasting changes in all components of climate system and these changes will do irreversible damage to the planet earth.

2. Global Warming and Air Pollution

Air pollution is defined as the presence of such material in the air which when in large quantity affect the environment in harmful manner. Such materials are called air pollutants. There are different air polluting agents which are causing the increase in the temperature of environment. As per the study the greenhouse gas Carbon dioxideis the main air pollutant that is warming the Earth. One of the characteristics of this gas is its ability to survive in the atmosphere for longer period. It may survive for many centuries and this amplify its heat trapping effects with time. Over the last century the global average temperature has increased by more than 0.7 ^{0}C. The decade 2001-2010 is the warmest since 1880 (the earliest year for which global temperature record is available). Carbon dioxide is emitted when living beings breathe but this is not considered as air pollutant. The gas becomes air pollutant when it is emitted by agents like vehicles, power plants, burning of fossil fuels like gasoline. In last 150 years, such activities have resulted into increasing the amount of carbon dioxide into the atmosphere at such levels which is higher than that have been for thousands of years. This has rapidly increased the temperature of the Earth. A per an estimate by the World Health Organization (WHO) more than 1500,000 people die each year because of their exposure to airborne particulate matter. Air pollution is not a new problem but it has its traces to the middle ages. At that time the use of coal in cities such as London was beginning to increase.

The poor urban air quality is documented in the end of 16th century also. In 1952, there was fog all-around of London which was caused by the burning of coal in large scale. This fog was named as Black Fog as it has caused more than 4000 deaths at that time which was a huge count. However, it was during the decade of 1980, that the air quality became a big problem due to increase in number of vehicles in urban areas. Vehicular movement within and across cities gave birth to the problem of air pollution. In the starting of 1980 decade the main focus was on to study the impact of lead pollution on human health but later on the other air pollutants released by the vehicular movement also became a major cause of concern. Two of the major disasters of air pollution were the release of hydrogen sulphide at Poza Rica, Mexico in 1950 and toxic release at Bhopal, India. The recent efforts to reduce air pollution is based on the evidence that air pollution is causing significant increase in mortality. The efforts are focused on reducing air pollution through regulation of both stationary and mobile sources of air pollutants. Air pollution causes respiratory diseases and large number of deaths worldwide. One of the ways to tackle the problem of global warming is finding ways and means to evaluate environment so that policy makers can come up with policies/methods to address the same. Global warming can be tackled on two fronts *viz* cutting pollution and expanding clean air. The reductions in emissions of NOx, SO_x, and particulate matter (PM) from unregulated industries and heavy duty vehicles are supposed to result in wide spread reductions in concentrations of particulate matter in the air. Such improvements in air quality are proved to give better results so as toproduce substantial benefits in various dimensions of human life.

3. Environment Evaluation

Valuations of environmental resources are important for the following reasons:

1. To develop a generalized system of economic and natural resource accounting for estimating the environmentally corrected GDP.
2. To justify the investments or expenditures made for the benefits from preservation.
3. To design pollution taxes

Environmental resources such as atmosphere, water, and forests are natural resources that are regarded as renewable in the natural resource economics. The other category of natural resources i.e. minerals, fossil fuels etc. are considered as exhaustible resources. Environmental resources are non-exhaustible in the sense that they provide a sustainable flow of services if their quality is maintained at the natural regenerative level. Services provided by them have the properties of indivisibility and non-excludability. The atmosphere provides waste receptive services and savings in health damages to people if pollution loads do not exceed the levels that affect its regenerative capacity. The water resources provide waste receptive services, environmental amenity services, and benefits from supporting aquatic life or bio-diversity. The preserved forests conserve soil, control floods, preserve biodiversity and act as a carbon sink. Such benefits from environmental resources are classified into two types *viz* for user benefits and for non-user benefits. In type of user benefits we keep such benefits which are related to enjoyment, recreational, aesthetic and health. These benefits are for those persons who either visit or use these resources.In other case, there are persons who feel that they will be benefitted merely by existing of the resource although such persons do not visit the place or site. Such benefits are clubbed into non-use benefits (Krutilla, 1967; Fisher and Krutilla, 1975). Weisbrod (1964) had proposed another classification of benefits and added another category *viz* option value. Option values is defined as a premium on resource which will be paid by the future user to make use of such resource. This is the value which a user ready to pay to avail or visit a particular resource. Thus the total environment benefits are classified into three types *viz* use, non-user and option value. Valuation of environmental resources poses difficult problems. Current environmental economics literature (Freeman, 1993) [8] describes various methods that are specially designed to value environmental resources. These methods may be classified as physical linkage, maintenance cost and behavior linkage methods. Mitchell and Carson (1993) have further classified behavioral methods as (a) methods based on observed behavior and (b) hypothetical methods. The first set of methods includes travel cost, hedonic prices, and household production models while the second set of methods includes contingent valuation and various variants of it (Freeman, 1993) [8]. While the travel cost and hedonic prices methods can be used to measure only direct user benefits like recreational benefits and health benefits, the contingent valuation methods can be used to measure both user and non-user (existence and bequest values) benefits. Contingent valuation methods are used not only for valuing environmental externalities like recreation, bio-diversity etc. but also for valuing private goods like health, water supply, education etc. for which markets may be imperfect or incomplete. The environmental values should form part of net national product (NNP) of a country. In the conventional method of measuring NNP, zero values are assigned to environmental services and they are considered as free services.

4. Methods of Estimating Benefits from Environment Valuation

Mathematicians and economists have made sincere efforts to develop method and models so as to estimate the benefits for improving quality of environment. Such methods and models are primarily aimed at capturing primary benefits for the people or society. In such models it is assumed that secondary benefits to the people or society are generally equated by secondary costs and therefore not to be included into total benefits. Smith and Krutilla (1982) [20] presented a general classification of measuring benefits of environment improvement into two categories:

1. Physical Linkage Methods
2. Behavioral Linkage Methods

4.1 Physical Linkage Methods

In such methods, the benefits are captured based on technical relationship between the user and the resource. Damage Function Method is an example of such approach.

4.2 Behavioral Linkage Methods

These methods are based on observations of behavior. In these methods environment goods are observed either in actual market or in hypothetical market using responses through surveys of users. These methods can be further divided into two types –

a. Direct Methods: In these methods the responses related to changes in environment attributes are studied directly e.g. Contingent Valuation Method, Political Referendum Method
b. Indirect Methods: In these methods, the responses are studied not only about the environment attributes but also about the market conditions related to such attributes. Examples of such methods are Averting expenditure method, Travel Cost Method and the Hedonic Price Method

5. Hedonic Price Function

This method is used to estimate the value of an attribute of environment resource. It is also used to identify how an environment service impact the market price of the same. The economic value of ecosystem can be evaluated using this method. This method is quite useful in identifying the variations in prices/rent of houses vis-à-vis any particular environment attribute. In broad sense, this method is can be used to estimate economic costs or economic benefits associated with:

- Quality of environment measured through pollution *viz* air, water or noise
- Amenities like aesthetic views of environment resources or proximity to sites which have recreational values

The hedonic method is based on the premise that the price of a good is related to its attributes (including service) provided the good is marketed. For example, the price of a car is determined by its attributes (characteristics) such as mileage, comfort, luxury, ease of transportation among others. Thus the car is reflected by its characteristics. So one can estimate the value of its individual characteristic by finding the price which the people are placing on it. It is assumed that price of an attribute changes with the change in attribute. This method is mostly used to estimate the value of environment attribute which impact the price of housing property. If we go by the meaning of the term hedonic then we find that this term is used to describe the relative importance of different attributes of a particular object. The term hedonic was therefore used to construct the index of usefulness of various attributes of any particular object.

Rosen (1974) [19] defines hedonic prices as "the implicit prices of attributes and are revealed to economic agents from observed prices of differentiated products and the specific amounts of characteristics associated with them" (Ustaoğlu, 2003). It was Rosen (1974) [19] who presented a theory to determine the implicit value of an attribute of an object. This theory is based on the value which different consumers put on different attributes of the object. This value is defined by Rosen as bid price of the attribute or characteristics. Thus the bid price of an attribute of a good is defined as the price which a customer is willing to pay so as the level of attribute for that particular good remains the same. The bid price is given by the maximum price. In his theory, the tangent of the market price curve is used to gather the information about the rate of change in price of the attribute in equilibrium conditions. The bid price function for consumer is identified using this method. Rosen also discussed producer's offer function using this method. While he defined bid price as the maximum price, the offer function is defined as the minimum price which a producer is willing to accept to sell a good so as to make a certain profit from this.

In hedonic price method, the hedonic model is constructed with the help of two equation. The first equation gives hedonic function and the second equation defines marginal willingness to pay function which is constructed for improved environment attribute.

The equations for hedonic function are given as –

$$P = P(N, S, Q)$$

where P is the Price function, N the neighborhood attributes, S the structural attributes and Q represents the environmental attributes.

6. Functional Forms of Hedonic Function

In many of the papers that make use of the hedonic methodology, the functional forms of hedonic function are restricted in the sense that mostly linear, semi-log or at the most trans-log forms are used. The use of Box-Cox (1964) [2] method for choosing appropriate functional forms is suggested by Griliches (1967) [10]. This functional form includes the log-log, semi-log, square root and quadratic forms among others. Halvorsen and Pollakowski (1981) provided a combination of functional forms along with the Box-Cox transformations. They presented a generalized model of different functional forms *viz* the quadratic Box-Cox functional form. In hedonic model, there are four most commonly used functional forms which are variants of the Box Cox model. It is given as:

$$P^{\theta} = \alpha_0 + \sum_{i=1}^{m} \alpha_i X_i^{(\lambda)} + \frac{1}{2} \sum \sum \gamma_{ij} X_i^{(\lambda)} X_j^{(\lambda)} \ldots \quad (1)$$

where P represents the Price, X_i's the characteristics of the good while P^{θ} and $X^{(\lambda)}$ are the Box-Cox transformations. We have -

$$P^{\theta} = \frac{P^{\theta} - 1}{\theta}, \forall\, \theta \neq 0$$

$$= LnP, \forall\, \theta = 0$$

$$X_i^{(\lambda)} = \frac{X_i^{(\lambda)} - 1}{\lambda}, \forall\, \lambda \neq 0$$

$$= LnX_i, \forall\, \lambda = 0$$

Since the limit for the case $\theta \neq 0$ as $\theta \to 0$ is LnP and the limit for $\lambda \neq 0$ case as $\lambda \to 0$ is LnX, therefore these transformations are proved to be continuous around $\theta = 0$ and $\lambda = 0$.

Adding stochastic term to the quadratic model given by equation (1), we get –

$$P^{\theta} = \alpha_0 + \sum_{i=1}^{m} \alpha_i X_i^{(\lambda)} + \frac{1}{2} \sum \sum \gamma_{ij} X_i^{(\lambda)} X_j^{(\lambda)} + \epsilon_i \quad (2)$$

The term ϵ_i shows the random error of the model. It represents the net effect of all the factors/variables which are excluded from the model.

Imposing restriction on θ and λ in equation (1), we get various functional forms for hedonic function e.g. if we put $\theta = \lambda = 1$ then we get the quadratic form, if we put $\theta = 2, \lambda = 1$ we get the square root form. Below are some of the basic functional forms of hedonic function -

6.1 Linear Form: The simplest approach is the ordinary linear form given by –

$$f(z_{1,}z_{2,}\dots\dots z_n) = \alpha_0 + \sum_{n=1}^{N}\alpha_n z_n$$

Hedonic prices are given by:

$$\frac{\partial f}{\partial z_n} = \alpha_n$$

The regression coefficient α_n (n=1,2…..,N) represents the marginal change in price with respect to a change in n[th] characteristic of the good.

6.2 Log Form: The logarithmic model of the hedonic function is given as:

$$f(z_{1,}z_{2,}\dots\dots z_n) = \alpha_0 + \sum_{n=1}^{N}\alpha_n lnz_n$$

Hedonic prices are given by:

$$\frac{\partial f}{\partial z_n} = \frac{\alpha_n}{z_n}$$

6.3 Log – log Form: In the *log-log model*, the hedonic aggregator function *f* is defined in terms of its logarithm. It is derived from power function as:

$$f(z_1, z_2, \dots\dots z_n) = \alpha_0 \prod_{n=1}^{N} {z_n}^{\alpha^n}$$

Or

$$\ln f(z_1, z_2, \dots\dots z_n) = \alpha_n + \sum_{n=1}^{N}\alpha_n\, lnz_n$$

Hedonic prices are given by

$$\frac{\partial f}{\partial z_n} = \frac{\alpha_n}{z_n} f$$

where α_n are the unknown parameters to be estimated.α_n indicates percentage change in price function f if the n[th] characteristic z_k changes by one percent.

6.4 Exponential Form: The exponential model is given as:

$$f(z_1, z_2, \dots\dots z_n) = \alpha_0 \prod_{n=1}^{N} \exp(\alpha_n z_n)$$

Or

$$\ln f(z_1, z_2, \dots\dots z_n) = ln\alpha_0 + \sum_{n=1}^{N}\alpha_n z_n$$

Hedonic prices are given by:

$$\frac{\partial f}{\partial z_n} = \alpha_n f$$

The coefficient $\alpha_n$represents the rate at which the price increases at certain level for n[th] characteristic z_n

Thus hedonic function is estimated as multiple regression model. We formulate multivariate hyperplane as

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \cdots + \beta_m X_m + \epsilon$$

where Y is dependent variable,X_1,X_2,……,X_m are explanatory variables or regressors. Here the termϵ denotes the random error. This model is called linear regression model because it is linear in the parameters $\beta_0, \beta_1, \dots., \beta_m$. In this model we make some assumptions as:

1. Mean of the error term is zero
2. The error is normally distributed
3. X and ϵ are uncorrelated i.e. Cov(X, ϵ) = 0
4. X is nonrandom variable with finite variance
5. There does not exist any exact linear relationship between the $X_j's, j = 1,2, \dots m$ i.e none of the explanatory variable is perfectly correlated with any linear combination of other explanatory variable.

For fixed $X_j's, j = 1,2, \dots m$,the population regression hyperplane is defined as the conditional mean of Y given the $X_j's$ or

$$E(Y|X_1, \dots X_m) = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \cdots + \beta_m X_m \quad (3)$$

as $E(\epsilon) = 0$. The parameters $\beta_0, \beta_1, \dots., \beta_m$are unobserved and must be estimated from sample data. From equation (3) we have –

$$\beta_0 = E(Y|X_1 = 0, \dots X_m = 0) \quad (4)$$

The coefficient β_j is given by –

$$\beta_j = \frac{\partial E(Y|X_1, \dots X_m)}{\partial X_j}, j = 1,2, \dots\dots, m \quad (5)$$

It is called the j[th] partial regression coefficient. This gives the change in average value of Y when the variable associated namely X_j is increased by one unit assuming that all other regressors are constant. Once the values of all the partial regression coefficients $\beta_j$are estimated from sample data, we get the regression hyperplane -

$$\hat{Y} = \hat{\beta}_0 + \hat{\beta}_1 X_1 + \cdots + \hat{\beta}_m X_m \quad (6)$$

where $\hat{Y}$ is the estimated value of Y and the $\hat{\beta}_k's$ represents the estimates of the population parameters. The i[th] residual is given by the term$e_i = Y_i - \hat{Y}_i, i = 1,2, \dots. n$. The population parameters $\beta_0, \beta_1, \dots., \beta_m$are estimated either using least square method or by maximum-likelihood estimation.

Conclusion

Global warming and air pollution are interrelated. By controlling air pollution, the threat of global warming can be mitigated. One approach to control air pollution is to make people aware about monetary benefits attached to reduced air pollution. This can be done by putting value to environment amenities and in particular to air pollution. Hedonic method is very lucid and simple method to be adopted for this purpose. Various functional forms of Hedonic Function are variants of Box-Cox model. Hedonic model can be fitted for a sample data using multiple linear regression. The problem with this method is that it does not incorporate non-linear relationship between variables. Also the functional form is highly dependent on the quality of data. If the data quality is poor then the hedonic function fails to estimate demand function. The choice of appropriate functional forms for the hedonic model is very important. For this we can start with the more general quadratic Box-Cox functional form for the hedonic function and then a number of functional forms can be considered.

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