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CLIMATE CHANGE AND HUMAN HEALTH : QUANTIFYING WILLINGNESS TO PAY FOR AVERTING MORBIDITY IN KERALA, INDIA

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Abstract

Climate change causes tangible impacts on human health, which directly affects the wellbeing of the people. Many studies observed positive correlation between Willingness to Pay and incidence of climate change variables. This study uses carbon presence, CO as a dummy for climate change in select three locations of Kerala and estimates average WTP for high and moderate carbon areas as 6273.70 and. 4413.71 respectively, showing clear evidence that average willingness to pay is positively influenced by climate variations. The study thus concludes that climate change concerns have the capacity to influence Willingness to Pay of the people positively and significantly.

***Keywords* :** Climate Change, WTP, Air Pollution, CO_2.

Introduction

Climate change is one of the most important threats for the existence of the human society and a major constraint for development. Several cases have reported all over the world related to the mitigation of greenhouse gas emissions and the adaptation strategies of local communities to deal with the impact of climate change on various sectors (Agarwal, 2008; Klein *et al*., 2003; Pielke, 1998). Human activities have increased the levels of greenhouse gases, such as, carbon dioxide, methane, nitrous oxides, and chlorofluorocarbons (CFCs) and these gases contribute to the warming of earth's atmosphere which lead to climate change and increased risk for human beings.

It is observed by Hannah Ritchie and Max Roser, (2020) that India is the fourth highest emitter of carbon dioxide in the world, accounting for 7 percent of global emissions. The state of Kerala, in the southern tip of India, is identified as one of the most vulnerable areas in in natural disasters and climate change risks (KSAPCC, 2014, GoK, Sarun and Sheela, 2018). Risk exposure to climate change is high in Kerala due to its unique geographical conditions and weather extremes. The Kerala PDNA team on Floods and Landslides, 2018 observed that Kerala is highly vulnerable to natural disasters and climate change due to its location along the seacoast and steep gradient. Risks due to climate change has been caused specific vulnerabilities in the state economy, especially in agriculture, animal husbandry, water resources, fisheries and coastal resources, transportation, and tourism.

Many attempts have been made all over the world to assess the monetary values of climate change risk (Longo *et al*., 2012; Botzen *et al*. 2012, Li *et al*., 2016). As India is one of the highest emitters of carbon dioxide in the world, the people's willingness to pay to avert health risks due to increased CO has not been studied well. In most of the industrial cities the world over, consumers expressed their strong preference for environmental quality and willingness to pay for it. People's Willingness to Pay (WTP) has been influenced by presence of air polluting agents and local amenities such as environmental quality, social capital and health capital. The increasing CO affects the health and welfare of the people and this aversive behaviour of households due to increasing CO can be taken as their WTP to avoid this welfare losses. The primary concern of this inquiry is to study how CO, as a representative of climate change, influences human health in Cochin, Kerala, India by estimating WTP due for reduced CO. We adopt the Revealed Preference Approach to estimate monetary values of welfare losses.

Materials and Methods

The household health production function model adopted in this study taken from the Grossman (1972), Cropper (1981) and Alberini and Krupnick (2000), and is used to estimate the values that households place on change in health due to change in climate change, CO. The model starts with a notion that climate change is a function of air pollution, particularly, CO.

$$\text{Climate Change} = f(CO) \qquad ...(1)$$

The health production function is specified as

$$S = s(C.M.H.K.) \qquad ...(2)$$

Where,

S = Number of sick days

C = Environmental Quality, CO

M = Mitigating Activities

K = Stock of social capital (such as education, sex….)

H = Stock of health Capital

The utility function of the individual household is defined as

$$U = u\ (X, S, C, L, Y) \qquad ....(3)$$

Where,

X = any private good, taken as numeraire

L = leisure

Y = Income

Individual's budget constraint is written as, Y = Y * + Pw (T – L – S) = X + Pm.M ...(4)

Where,

Pw = wage rate

*Y** = non labour income

T = total time available

Pm = price of mitigating activities

Individual maximizes Utility (2) subject to the budget constraint,

$$Max\ Z = u\,(X,S,C,L,I) + \lambda\,(Y* + Pw\,(T - L - S) - X - Pm.M) \quad ...(4)$$

First order condition for maximization is,

$UX = \lambda$ ...(5.1) where $Uy = \frac{\partial U}{\partial X}$

$U_L = \lambda\ Pw$ ...(5.2) where $Uy = \frac{\partial U}{\partial C}$

$U_S\,.S_M = \lambda P_W S_M + \lambda P_M$,

$$\frac{\lambda P_M}{S_M} = U_S - \lambda P_W \quad ...(5.3),$$

from (5.3), we can write,

$$\lambda P_M = U_S.S_M - \lambda P_W.S_M \quad ...(6)$$

the indirect Utility function is given as,

$$V = v(c, P_M, H, K, Y) \quad ...(7)$$

by taking total differential of this function and equating to Zero, one gets,

$$dV = Vc.dc + Vp_M.dP_M + V_I.dY = 0$$

Assuming P_M is optimum $\partial P_M = 0$;

$$\frac{dI}{dC} = -\frac{V_C}{V_I} = -\frac{V_C}{\lambda} \quad ...(8)$$

Considering the lagrangian function for maximization as indirect utility function and differentiate with respect to Y we get, $V_I = \frac{\partial V}{\partial Y} = \left(\frac{\partial Z}{\partial Y}\right) = \lambda$

similarly, Z (equation 5) as V and differentiate with respect to 'C' we get

$$= U_C + S_C(U_S - \lambda P_W) \quad ...(9)$$

substituting (6) in (9) we get

$$\frac{\partial I}{\partial C} = \frac{U_C}{\lambda} + \frac{S_C}{\lambda}\left(\frac{\lambda P_M}{S_M}\right)$$

$$\frac{\partial I}{\partial C} = -\frac{V_C}{\lambda} = -\left(\frac{U_C}{\lambda} + \frac{P_M S_C}{S_M}\right) \quad ...(10)$$

Equation (10) gives the Marginal Willingness to Pay for individual for improved environmental quality.

The demand function for M is estimated as,

$$M = M\,(W, P_M, C, Y, H, K) \quad ...(11)$$

These equations give optimum quantities of *M*.

The total derivative of health production function is taken,

$$\frac{dS}{dC} = \frac{\partial S}{\partial M}.\frac{\partial M}{\partial C} + \frac{\partial S}{\partial C} \quad ...(12)$$

This can be re written as

$$\frac{\partial S}{\partial C} = \frac{dS}{dc} - \frac{\partial S}{\partial M}.\frac{\partial M}{\partial C} \quad ...(13)$$

Multiply equation (10) with the first order condition given in (6)

$$\frac{-P_M}{\partial S/\partial M} = P_W - \frac{\partial U/\partial S}{\lambda} \quad ...(14)$$

Thus we get $\frac{\partial I}{\partial C}$ i.e. MWTP. $\frac{\partial I}{\partial C}$ in equation number (10) can be approximated to

$$\frac{\partial I}{\partial C} = -P_M.\frac{\partial S/\partial C}{\partial S/\partial M} = -P_M\left(\frac{S_C}{S_M}\right) \quad ...(15)$$

Since *Uc*–direct utility gains that cannot be captured by Household Production function, i.e,

$$-P_M.\frac{\partial S/\partial C}{\partial S/\partial M} = \frac{\partial S}{\partial C}\left(P_W - \frac{\partial U/\partial S}{\lambda}\right) - \frac{\partial S}{\partial M}.\frac{\partial M}{\partial C}\left(P_W - \frac{\partial U/\partial S}{\lambda}\right) \quad ...(16)$$

Substituting from (14) and rearranging, we will get, MWTP as

$$MWTP.\quad \frac{\partial I}{\partial C} = P_W\frac{\partial S}{\partial C} + P_M\frac{\partial M}{\partial C} - \frac{\partial U/\partial S}{\lambda}.\frac{\partial S}{\partial C} \quad ...(17)$$

This expression shows that marginal willingness to pay (MWTP) for health benefits from reduced levels CO is the sum of observable reductions in the cost of illness, cost of mitigating activities and the monetary equivalent of disutility of illness due to air pollution (Freeman 1993).

2.1 Environmental Quality and Socio-Economic Characteristics

To estimate WTP using the health production function, we collected cross sectional data for of 300 households on CO levels in three stations to which the individual is exposed, epidemiological data experienced by households, actions and costs associated to avoid or mitigate effects of CO of households and Other health variables. The CO status for all the three monitoring stations in Cochin is given in figure 1. This chart reveals that the CO concentration exceeds the maximum tolerance level for residential areas in Vyttila. Morbidity is measured by recorded cases of different types of illness. The morbidity data collected from the study area during the survey reveals high incidence of headache, cough, asthma eye irritation and recurrent fever in the study area.

Results and Discussion

3.1 Estimation of Marginal Willingness to Pay (MWTP)

Estimation of willingness to pay using household health production function is attempted in three steps. In the first step, we regressed 'number of doctor visits' (*drvisit*) on CO dummies and other socio-economic variables to see how a person's doctor visits influenced by air quality variable. This is taken as the demand for mitigating activities. In the second step, health production function is estimated considering by regressing restrictive activity days (RAD) as the dependent variable using two stage least square (TSLS) model. The estimated coefficients are thus used in the third step to estimate MWTP.

The dummies in each variable case in fitting regression is specified. For CO, the three stations are divided in to– low CO area, taken as the base category with value zero, moderate CO area by value pd1 and high CO area by pd2. In education, total respondents are divided into four classes and below SSLC is taken as the base category. ed1 indicates SSLC / +2, ed2 for Graduate/Engineering and ed3 for PG/Professional. In case of disease, dummies are 0 for 'No' and 1 for 'Yes'.

3.2 Estimating Demand for mitigating activities

Ordinary Least Square (OLS) Regression is used to estimate the coefficient of doctor visits with respect to pollution. The regression equation is specified as follows:

$$drvisit = \alpha_0 + \alpha_1 \text{MONTHLY INCOME} + \alpha_2 \text{MTNGCOST} + \alpha_3 \text{PD1} + \alpha_4 \text{PD2} + \alpha_5 \text{ASTHMA} + \alpha_6 \text{BRONCHITIS} + \alpha_7 \text{EYE IRRITATION} + \alpha_8 \text{RECFEVER} + \alpha_9 \text{ED1} + \alpha_{10} \text{ED2} + \alpha_{11} \text{ED3} + \alpha_{!12} \text{INSURANCE} + \varepsilon$$

Where,

α_0 = constant,

drvisit = Doctor visit.

MTNGCOST= Mitigating cost

PD1 = Pollution dummy for moderate polluted areas (MG Road)

PD2 = Pollution dummy for highly polluted areas (Vyttila)

RECFEVER = Recurrent fever

ED1 = Education dummy for SSLC / +2

ED2 = Education dummy for Graduate/Engineering

ED3 = Education dummy for Post Graduate/Professional.

The equation above shows people's demand for mitigating activities as a function of CO, income, social capital like education and individual's health stock. The regression results are presented in table 1 (Source: Regression results – demand for mitigating activities). The pollution coefficients, pd1 and pd2 [α_3 =2.86 and α_4 =6.63] are positive and significant at 1% revealing that the demand for mitigating activities is positively determined by CO. It is found that in moderate pollution area (MG Road), the doctor visits (drvisit) is higher by 2.86 units than the low polluted area (Eloor), whereas, in the highly polluted area (Vyttila) it is higher by 6.63 units. Variables of mitigating cost and monthly income are significant at 1% level, but the influence on the number of doctor visits is very meagre. Among the health variables, bronchitis is highly and positively significant. It is interesting to note that in all three sections, demand for mitigating activities is negatively related to education. It is evident that educated people undertake more averting and mitigating activities other than doctor visit positively, because of their awareness regarding the impact of change on CO on their health.

3.3 Estimating Health Production Function

'Restrictive activity days' (RAD) is used as the dependent variable to estimate health production function. RAD is hypothesized as a function of various socio-economic variables, such as, monthly income, doctor visits, CO, occurrence of diseases, education, smoking, insurance and age. Two Stage Least Square (TSLS) was has used to estimate mitigating activity and health production function simultaneously. The data were checked for identification problem. The following is the regression equation used to estimate health production function:

$$RAD = \beta_0 + \beta_1 \text{MONTHLY INCOME01} + \beta_2 \text{MTNGCOST} + \beta_3 \text{PD1} + \beta_4 \text{PD2} + \beta_5 \text{ASTHMA} + \beta_6 \text{BRONCHITIS} + \beta_7 \text{EYE IRRITATION} + \beta_8 \text{RECFEVER} + \beta_9 \text{ED1} + \beta_{10} \text{ED2} + \beta_{11} \text{ED3} + \beta_{!12} \text{INSURANCE} + \varepsilon$$

Where,

β_0 = constant,

RAD = Restricted activity days

MTNGCOST = Mitigating cost

PD1 = Pollution dummy for moderate polluted areas

PD2 = Pollution dummy for highly polluted areas

RECFEVER = Recurrent fever

ED1 = Education dummy for SSLC / +2

ED2 = Education dummy for Graduate/Engineering

ED3 = Education dummy for Post-Graduate/Professional.

TSLS Regression results for estimating health production function are reported in table 2 (Source: Regression results - estimating health production function). Coefficients of pollution dummy remain positive and significant at 1% level of significance. Restrictive activity days (RAD) in moderate pollution areas are higher by nearly 11.91 percent and higher by 18. 15 percent compared to less polluted areas. Coefficient of mitigating demand is positively related to RAD and significant at 1 percent. Coefficient of recurrent fever is higher, 2.43, demonstrating that recurrent fever causes more RAD. As in the case of demand for mitigating activity already explained above, all the education dummies are negatively related to RAD. Co-efficient of insurance and smoking are significant at 5 and 10 percent levels respectively, representing that RAD are higher for insurance holders (1.34) and smokers (1.91).

3.4 Estimating Willingness to Pay

The willingness to pay of individual household's for health benefits due to the reduced levels of CO is the sum of value of lost working time, observed changes in averting/ mitigating activities and the monetary equivalent of disutility of illness due to air pollution and is estimated as below (Cropper and Freeman 1991).

$$WTP, \quad \frac{\partial Y}{\partial C} = P_W \frac{\partial S}{\partial C} + P_M \frac{\partial M}{\partial C} - \frac{\partial U / \partial S}{\lambda} \cdot \frac{\partial S}{\partial C}$$

where, λ the marginal utility of income, converts the disutility of illness into monetary terms and $\frac{\partial M}{\partial C}$ gives the optimal adjustments of M (demand for mitigating activities) to a change in air pollution. The first two terms in the equation can be approximated by using the observed changes in illness and mitigating expenditures as the last term, representing the effects of disutility of illness could not be estimated[1].

[1]As a practical matter by avoiding monetary equivalent of disutility of illness $\left(\frac{\partial U/\partial S}{\lambda}.\frac{\partial S}{\partial C}\right)$, the observed lower bound of WTP is referred to as, *Private Cost of Illness* or the cost borne by an individual for mitigating and averting expenditures and lost time (Cropper and Freeman 1991).See section 2. 1.1 for detailed theoretical review.

Average area wise estimate of willingness to pay (WTP) is calculated and given in table 3. The mean willingness to pay for the highly polluted areas (Vyttila) is Rs. 6273.70 and for moderate polluted areas (M G road) is 4413.71 respectively. WTP for Eloor, the less polluted area is assumed to be zero as pollution dummy is assumed as zero.

Conclusion

Climate change mitigation activities and their monetary valuation is important at policy level. Human activities have increased the levels of greenhouse gases in the air and these gases contributed to climate change and increased risk in humanity, worldwide. This study tried to estimate the willingness to pay for averting 'risk days' of selected households in Cochin, Central Kerala, India which is highly vulnerable to natural disasters due to climate change. Willingness to pay was estimated using two-stage regression analysis for selected 300 households. The results showed that the coefficient of air pollution (CO) is positive and highly significant to doctor visits and restrictive activity days. The average WTP for the highly polluted areas of Cochin is Rs. 6273.70 and moderate polluted area is Rs. 4413.71 respectively, showing clear evidence that average willingness to pay is positively influenced by CO, which leads to climate variations.

This study proposes a major insight in valuing environmental goods. In an informed society, the average willingness to pay for environmental goods and amenities are higher. Hence WTP distributions can be used as an instrument for pricing environmental goods and hence estimating the demand function. Average WTP can also be used at policy level to identify and mitigate the impacts climate change.

Table 1 : Regression results - Demand for Mitigating Activities

Dependent Variable: DOCVISIT			
Method: Least Squares			
Sample: 300			
Included observations: 300			
Variable	Coefficient	Std. Error	t-Statistic
C	5.278191*	1.580062	3.340496132
MONTHLY INCOME	0.000336*	7.88E-05	4.263959391
MTNGCOST	0.00074*	0.000204	3.62745098
PD1	2.861851*	0.648475	4.413201743
PD2	6.636292*	0.812365	8.169101328
ASTHMA	-0.118097	0.487454	-0.242273117
BRONCHITIS	3.468259*	0.567883	6.107347816
EYE_IRRITATION	-0.641387	0.682448	-0.939832778
RECFEVER	2.320741*	0.517705	4.482747897
ED1	-1.9726284**	0.698376	-2.824593629
ED2	-2.221922*	0.848363	-2.619069903
ED3	-4.584353*	1.213087	-3.779080148
SMOKING	0.341311	0.493953	0.690978696
INSURANCE	0.026161	0.453977	0.057626267
AGE	0.014981	0.022714	0.659549177
R-squared	0.468307	Mean dependent var	10.78133
Adjusted R-squared	0.452172	S.D. dependent var	6.96125
S.E. of regression	5.262910	Akaike info criterion	6.191004
Sum squared resid	15984.69	Schwarz criterion	6.239927
Log likelihood	-1910.201	F-statistic	33.14654
Durbin-Watson stat	1.571127	Prob(F-statistic)	0.000000

*,** significant at 1% and 5% respectively.

Table 2 : Regression Results – Estimating health production function

Dependent Variable: RAD			
Method: Two-Stage Least Squares			
Sample: 300			
Included observations: 300			
Instrument list: DRVISIT C MONTH_INCOME01 MTGCOST			
PD1 PD2 ASTHMA BRONCHITIS EYE_IRRITATION			
01 RECFEVER ED1 ED2 ED3 SOMKING INSURANCE AGE			
Variable	Coefficient	Std. Error	t-Statistic
C	4.861812	2.919414	1.665338318
MONTHLY INCOME	0.000219***	1.01E-04	2.168316832
DRVISIT	0.253822*	0.07166	3.542031817
PD1	11.91259*	1.004159	11.86325074
PD2	18.15279*	1.218687	14.8953669
ASTHMA	0.313934	0.918914	0.341635888
BRONCHITIS	1.851279***	1.002895	1.845935018
EYE IRRITATION	-0.873014	0.88066	-0.991317875
RECFEVER	2.426465*	0.863909	2.808704389
ED1	-1.879209	1.41697	-1.326216504
ED2	-4.217101*	1.423279	-2.962947532
ED3	-6.897743*	3.036497	-2.271611992
SMOKING	1.911167**	0.831494	2.298473591
INSURANCE	1.343894***	0.749577	1.792869845
AGE	-0.009856	0.037155	-0.265267124
R-squared	0.551782	Mean dependent var	20.73380
Adjusted R-squared	0.541961	S.D. dependent var	14.0111
S.E. of regression	8.898576	Sum squared reside	47240.31
F-statistic	49.73289	Durbin-Watson stat	1.6522
Prob(F-statistic)	0.000000		

*,** significant at 1%, 5% and 10% respectively.

Table 3 : Average Willingness to Pay of Households of Cochin by Stations

	Sample	Minimum	Maximum	Mean	Std. Deviation
ELOOR	100	00	00	00	00
MG ROAD	100	1356.25	8083.77	4413.71	1711.65
VYTTILA	100	1391.36	9929.29	6273.70	1985.44
WTP WHOLE SAMPLE	300	.00	9929.29	2883.63	2642.32

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