ECONOMIC VALUATION OF AIR POLLUTION

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Air as a Common Property Resource

- Non excludable resource – shared by all
- Obligation to preserve it
- Activities that cause air pollution
- Outdoor Air Pollution
  - Fossil fuels e.g. transportation, industry
  - Industrial process e.g. smelting, cement or asbestos production
  - Bio fuels like wood, crop residues &animal waste
  - Natural process e.g. Volcanic Activity, dust storms, forest fires
  - Refuse Burning

Indoor Air Pollution

- Sources
  - Cooking with bio fuels
- Major pollutants released
  - TSP – combustion of bio fuels (Exceed standards)
  - CO_2 – often exceed standards but less than
  - NO_X & SO_2 – consistent with standards of WHO & CPCB
- Organic Compounds
  - Formaldehyde, benzene, butadiene and benzopyrene

- Some Findings
  - Respiratory illness, eye and skin irritation, tuberculosis etc
  - Acute Respiratory Infection (ARI) is the single largest disease category for India with 1/8th of national disease
  - Harmful effects on the foetus
- Determinants of Indoor Pollution
  - Type of household fuel
  - Root type
  - Use of a chimney
  - Density of nearby housing
- Impact depends on exposure
  - Time hours spent near the resource of pollution
  - Availability of ventilation
  - Number &type of people exposed

A List of Externalities for Outdoor and Indoor Air Pollution

Broad Category	Impacts / Externalities	Application of Environmental Economics
Urban Air Pollution – non -transport	Premature Deaths Increased Illnesses Reduced Visibility Crop Loss Lower Economic Productivity Fall in Property Values Damage to Materials (buildings, vehicles, signs)	Quantification of Increase in Health Impacts Assessment of time and Income Losses Accounting of medical Costs, material Remediation, Property value Loss Monetization of Discomfort, Odor and visibility effects.
Rural Indoor Air Pollution	Premature Deaths Increased Illnesses- Respiratory, Lung , Heart Adverse Pregnancy Outcomes Eye and Skin Irritations Reduced Visibility Lower Economic Productivity Damage to materials (walls, ceiling, clothes, household goods) Foul Odor	Quantification of Increase in Health Impacts Assessment of time and Income Losses Accounting of medical Costs, material Remediation, Property value Loss Monetization of Discomfort, Odor and visibility effects.

Economic Valuation of SPM Emissions :

- Physical Linkage method

>the Dose Response Relationship

Elasticity across Pollution Concentration

And Mortality Rate : 0.09 to 0.12

Elasticity for Work Loss Day (WLD) = 0.45

Restricted Activity Day (RAD) = 0.39

Health Status Studies

- Morbidity Data Location : Bombay
  - Chembur (Urban Medium),
  - Parel (Urban High)
  - Railway Colony (Urban Low)
- Conduct Econometric Analysis by
- Physical linkage method by developing a dose – response relationship for morbidity and air pollutant levels, from the time series study on morbidity conducted in Chembur during 1978-1980
- A logit model for obtaining relationship between morbidity (cough / dyspnea) and pollutant levels

Time Series Study

- Data Sources
  - Household data where subjects maintained diaries over a certain time period
  - Data from hospitals on number of patients admitted on for respiratory disorders

The Econometrics

- Morbidity estimates
  - How much of the human mortality and morbidity suffered
    - » Cross sectional data for 300 households
  - Discrete morbidity variables
    - Subject not suffering from cough for 3 months = 1
    - Subject suffering for a longer period = 2 so on

Mortality Studies

- DR (Respiratory) % $_{WARD}$ =
- f(log(PDENS), SLUM, HOSP, log(SPM))

  Log PDENS :Log of the Ward Population Density

  Slum :Slum Population in a Ward

  Hosp :Number of Hospitals in Ward

  logSPM :Log of Concentration of SPM in_mg /m^3
- Dr (Respiratory)%$_{WARD}$ = - 0.062 + $3*10^{-7}$ lg PDENS + 5^{-7} SLUM – 0.0001HSOP + 0.0296logSPM

(n = 20, R^2 = 0.542)

Assumption Based on Medical Judgments for Cost of Increased Probability of Dyspnea

- 50% of people suffering from dyspnea have either bronchitis or asthma
- Bronchitis / asthma patient needs medical attention in the following manner
  - Mild attacks, 100 % once year
    - » No doctor visits
    - » One work day loss
  - Moderate attacks, 40 twice in an year
    - » Two doctor visits per attacks
    - » Three work days lost
  - Severe attacks 5% of total cases once in an year
    - » 5 days in hospital
    - » 10 work days lost

Data for Calculating Cost of Morbidity

Morbidity related Support Sought	Cost in RS (Range)	Cost in Rs (Average)
Medical Consultation(Our Patient)		
Doctors Fee (Per Consultation)	20/200	80
Cost of Diagnostic Tests (Per Case)	50-500	150
Medicines (Per day)	20-100	50
Transport (per Visit)	10-100	40
Hospitalization		
Doctor Fee	300-2000	1000
Diagnostic Tests	1000-3000	2000
Accommodation	2000-3000	500
Food (two Persons, per day)	50-300	150
Transport (per Stay)	200-1000	500
Full Time Assistant (rupees per Day)		51
Work Days Lost (Rupees Per Day)		51

Total Economic Value of Increased Dyspnea

Severity of Attack	People	Loss Suffered	Rupees (‘000s)	Total Rs. (‘000s)
Mild Attack	434276 (50%)	One Workday Loss	36045	36045
Moderate Attack	173710 (40%)	Consultation (80*2) Diagnosis (100) Medicine (50*5) Transport (40*2) Workdays Lost (3*51)	26309 16443 4110 13154 25157	129011
Severe Attack	21701 (5%)	5 days in Hospital Diagnosis Tests Consultation Food Transport workday Loss Patient) Workday Loss (Assistant) Meidcine		
Total Damage				223809

Mortality

- ¶DR / ¶SPM = 0.0296*1/ SM
- DDR (%) = 0.0296*_DSPM / SPM
- 100 unit change in SPM
- Excess deaths / deaths avoided = 0.0296*100 / (266) *Population of Bombay Exposed to specified levels of SPM
- Normal Respiratory Death rate = 0.08%
- Population of Bombay (19991) = 9909544
- Number of Respiratory Death = 0.08*9909544 / 100 =7928
- Due to all causes
- Number of excess Deaths / = 7928 * (0.0296*100/266) = 88.22
- Say 90 excess deaths per 100 unit increase in concentration in SPM
- Human capital Approach = Rs. 236,924
- Cost of Lives Lost /saved = 90* 236,924 = Rs 21,323,160
- Total Health Damages (Mortality 7 Morbidity) = Rs. 245,132,160 /-
- Damage per unit (1 mg /cum) increase of SPM = Rs 2,451,321

Expenditure per Individual Case of Dyspnea Attack

Severity of Sickness	Expenditure (Rs)	% of Annual Income
Mild attack	51	0.28
Medium attack	743	4.00
Severe Attack	7506	40.6

Impact of Air Pollution

- In 36 major Indian cities
  - 40350 premature deaths
  - 19805 thousand hospital admissions & medical treatment
  - 1201 million minor sickness annually
- Social cost of 10 ug increase in SO_2 in Mumbai is Rs. 100 million
- Human health damages due to air pollution in NCT, Delhi is Rs. 1168 million
- Indoor air pollution causes 0.41 to 0.57million premature deaths

Motivation

- Biofuels (wood, crop residue, dung cakes, saw dust) are major source of energy
- In India, 90 % rural households use biofuel

  Fuelwood (56%), animal dung (21%), crop residue (16%) [Teddy, 2000]

- Unprocessed biofuels normally cooked indoors

  Poor ventilation

  Inefficient cooking environment

→ Pollutants like Respirable Particulate Matter (RPM), poly aromatic hydrocarbons (carcinogen), noxious gases (NO_x, SO_2, CO) are released

→ Significant health effects on women, children and senior citizens

Yet, the association between diseases and fuel use has not been convincingly established

To do so….

Information on fuel use, socio-economic characteristics, demographic variable and symptom are reqd. from same individuals.

But….

Such integrated surveys are rarely available

Small sample

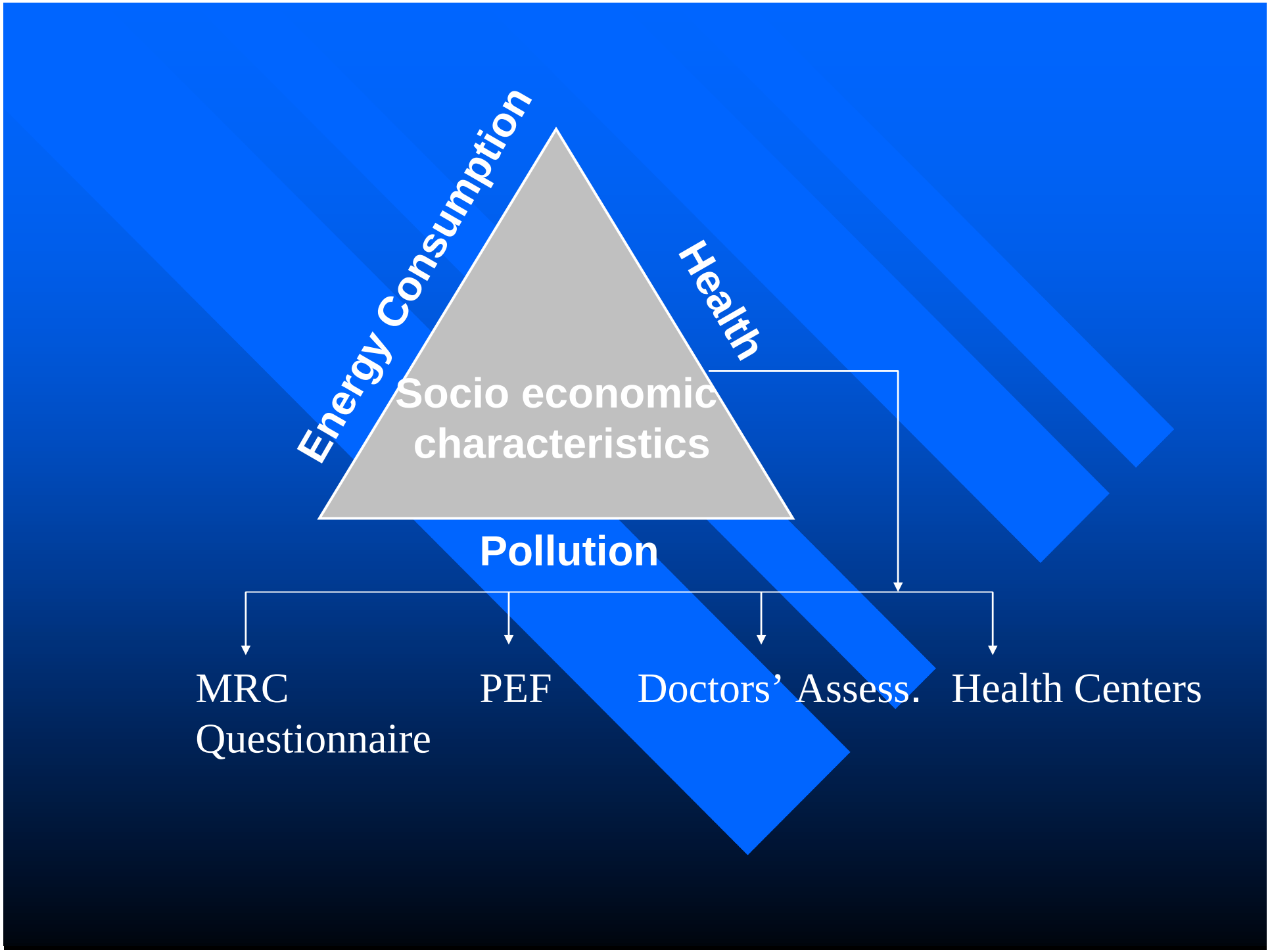
Confounding factors are not assessed and adjusted properly

Our analysis….

Comprehensive survey carried out over large sample

3 States (UP, RAJ, HP)

10263 households


Energy Consumption
Health
Socio economic characteristics
Pollution
MRC Questionnaire
PEF
Doctors' Assess.
Health Centers

Questions addressed

- Do exposures to biofuels affect peak expiratory flow (PEF) rates – which test lung functions, and occurrences of disease symptoms?
- How do the occurrences of respiratory and eye symptoms vary with individual attributes such as smoking, education and age?

- How do exposure variables such as location of kitchen, fuel use, hours of cooking etc affect the prevalence rate of symptoms?
- Can we develop an index to reflect lifetime exposure of the women?
- Do illiteracy, lower income, etc compound the risks to health from use of biofuels?
- Does household economic status matter and how can we represent it?

Sample Size

Sample/ State	Rajasthan	Uttar Pradesh	Himachal Pradesh	Total
Districts	3	9	6	18
Villages	13	54	51	118
Households	1989	712	7564	10265
Individuals	11955	4100	42713	58768

Data Collected

Individual Characteristics

Age Profile, Cooking Involvement, Literacy, Smoking, Occupation (including Dusty job), Height, Weight, Peak Expiratory Flow rates, Symptoms-Respiratory and Eye etc.

Household Characteristics

Housing-Kitchen characteristics,Energy Use, Income (Land, Per Capita Income, Livestock, Assets), Cooking Practices-meals cooked per day, hours of cooking, willingness to pay for interventions, etc.

Village Characteristics

Presence of Pucca road, Presence of city near by

Presence of railway station, etc

Determination of risk factors for rural energy use: An econometric approach

Testing of Hypothesis: Whether Biofuel affects health?

Observed : Peak Expiratory flow (PEF) rates(indicator of airways obstruction)

Subjective : Symptom ⟶ Diseases

a) Direct Responses

b) All Responses

(a) Biofuel-Clean Fuel users

(b) Cooking Involvement

(c) Male-Female

Created Variables

Fuel Index(FUELIND): reasonable proxy for exposure is fuel used

Other variables like – type of stove, time spent near the fire, kitchen location, even actual exposures using time activity pattern has been used

Our index serves as a proxy for cumulative exposure due to cooking activity

It has 3 components

- Type of fuel used
- Extent of cooking involvement
- Years of cooking

Example of calculation of FUELIND

Age	Years	Type of Involvement	Fuel Used
10-15	6	Never help	Wood
16-20	5	Sometimes Help	Dung
21-30	10	Chief Cook	Dung
31-40	10	Chief Cook	Kerosene
Above 40	4	Always Help	LPG

FUELIND = Years of cooking*Weight of fuel used*Weight of type of involvement

FUELIND=6*0.86*0.00+5*1.00*0.30+10*1.00*1.00
+10*0.08*1+4*0.05*0.75
= 12.45

Respiratory and Eye Symptoms per 1000 females

Symptoms	Per 1000 females			
	NIndia	UP	RAJ	HP
(a)Cough most days for 3 months/year	51	54	48	29
(b)Bring up phlegm for 3 months/year	35	37	31	21
(c)Shortness of breath when hurrying	112	106	100	187
(d)Wheezing in last 12 months	39	38	46	30
(e)Had chest illness in past 3 years	37	20	52	16
(f)Coughed blood in sputum	20	21	25	6
(g)Redness in eyes	62	59	92	29
(h)Watery eyes	92	90	120	59

Prevalence of disease per 1000 females

Diseases	Per 1000 females			
	NIndia	UP	RAJ	HP
Bronchitis	29	31	26	17
Asthma	21	19	28	22
Chest Infection	22	20	32	13
Tuberculosis	20	21	25	6
Eye Irritation	48	45	76	21

Disease Classifications:

Bronchitis: (a)+(b); Asthma=(c) +(d)but no to bronchitis; Chest infection=(e) + sputum formation;

Tb=(f); Eye irritation=(g) +(h)

Prevalence of disease symptoms for various variables (per 1000 individuals in the respective category)

Females(n=13340)	bronchitis		asthma		chestinf		tb		eye	
Total Symptoms	**391**		**277**		**288**		**272**		**638**	
Smoking		Chi-Sq		Chi-Sq		Chi-Sq		Chi-Sq		Chi-Sq
Smokers(n=1027,8%)	76.9	92.1*	33.7	9.6*	46.9	35.1*	31.9	7.6*		
Nonsmokers(n=12273,92%)	25.2		19.6		19.4		19.4			
Education										
Illiterate(n=9765,73.2%)	36.6	71.3*	25.0	34.0*	26.6	45.3*	24.8	40.0*	54.8	48.6*
Primary(n=1289,9.7%)	11.6		15.5		10.1		12.4		21.7	
Secondary(n=1481,11.1%)	6.8		4.1		6.1		4.7		25.7	
Higher(n=492,3.7%)	2.0		8.1		2.0		2.0		32.5	
NA(n=313,2.3%)										
Age										
15-30(n=6401,48%)	12.3	212.5*	7.5	165.9*	12.8	74.0*	12.8	41.6*	29.1	127.0*
31-45(n=3911,29.3%)	28.9		23.0		22.2		23.8		54.0	
46-60(n=2056,15.4%)	60.3		38.9		35.0		29.8		72.3	
>60(n=972,7.3%)	77.2		60.7		48.4		33.1		94.7	

* Sig at 1 %; ** Sig at 5%; *** Sig at 10 %

Pearson correlation coefficient between individual and household characteristics

	age	height	weight	PEF	illi	smoke	dusty	chief	acook	scook	ncook
age	1.000										
height	-0.071	1.000									
weight	0.028	0.198	1.000								
PEF	**-0.310**	**0.154**	**0.081**	**1.000**							
illi	0.303	-0.112	-0.051	**-0.150**	1.000						
smoke	0.166	-0.007	-0.049	**-0.084**	0.143	1.000					
dusty	-0.009	0.017	-0.012	**-0.018**	-0.012	0.023	1.000				
chief	-0.045	0.000	-0.007	**0.006**	0.093	-0.037	0.000	1.000			
acook	-0.084	0.017	-0.013	**0.012**	-0.122	-0.020	0.003	-0.411	1.000		
scook	0.044	-0.028	-0.039	**-0.021**	-0.084	0.010	0.000	-0.349	-0.118	1.000	
ncook	0.081	-0.010	0.067	**-0.003**	0.031	0.042	-0.024	-0.576	-0.194	-0.165	1.000
bfuel	-0.003	-0.091	-0.039	**-0.047**	0.354	0.071	-0.013	0.032	-0.059	-0.036	0.024
fuelind	0.765	-0.075	0.002	**-0.250**	0.331	0.128	-0.024	0.256	-0.068	-0.127	-0.150
hhmem	-0.015	0.050	0.027	**-0.002**	-0.044	0.002	-0.027	-0.116	0.081	0.052	0.016
sroom	-0.019	-0.099	-0.045	**0.013**	0.164	0.044	0.001	0.084	-0.069	-0.025	-0.023
sepkit	0.034	0.002	0.040	**-0.004**	-0.139	-0.055	-0.013	-0.078	0.058	0.014	0.069
outkit	-0.003	0.070	0.007	**0.019**	-0.065	-0.003	0.004	-0.005	0.026	0.018	-0.043
openair	-0.019	0.039	-0.008	**-0.025**	0.059	0.025	0.009	0.014	-0.023	-0.007	-0.023
assetn	0.001	0.129	0.148	**0.066**	-0.368	-0.089	-0.012	-0.125	0.086	0.061	0.034
nrooms	0.047	0.075	0.077	**0.014**	-0.214	-0.049	-0.017	-0.127	0.105	0.084	0.012
hours	-0.014	0.023	0.042	**0.021**	-0.104	0.003	-0.015	-0.114	0.070	0.066	0.052

Some conclusions from univariate analysis

- PEF strongly correlated with age, height and weight
- Smokers have significantly lower PEF values with odd ratios 1.5
- PEF lowers with age
- Biofuel cooking does not lower PEF(by chi-square)
- Inside kitchen as well as open air kitchen positive relation with PEF
- Education has positive impact on PEF
- Annual Household income is sig as per chi-square test

Some conclusions from univariate analysis

- Prevalence of resp and eye diseases is higher among smokers
- Among smokers prevalence increases with age(cumulative effect of smoking)
- Prevalence decreases with the level of education max decrease- illiteracy to primary education
- Strictly biofuel using HH prevalence reduces with the increase in the level of education.
- Steadily increases with age
- Chi-square associated with all disease classifications is significant
- Rates high in open air-poor status, low nutrition

Multivariate analysis under ordinary least square framework with PEF as dependent variable for all states

Parameter	Model 1		Model 2		Model 3		Model 4	
	Est	P>chi	Est	P>chi	Est	P>chi	Est	P>chi
Intercept	1.995	<.0001	2.220	<.0001	2.319	<.0001	2.163	<.0001
age	-0.023	<.0001	-0.025	<.0001	-0.026	<.0001	-0.026	<.0001
height	0.021	<.0001	0.020	<.0001	0.020	<.0001	0.020	<.0001
weight	0.012	<.0001	0.013	<.0001	0.013	<.0001	0.013	<.0001
smoke			-0.124	0.005	-0.128	0.004	-0.126	0.005
dustyjob			-0.334	0.008	-0.333	0.009	-0.347	0.005
bfuel			-0.073	0.084	-0.072	0.089		
chiefcook					-0.059	0.039		
acook					-0.103	0.012		
scook					-0.081	0.073		
fuelind							0.0003	0.853
Singlerm			0.082	0.044	0.081	0.045	0.084	0.037
Sepkit			-0.013	0.704	-0.014	0.701	-0.012	0.742
Openair			-0.084	0.036	-0.085	0.032	-0.088	0.026
assetn			0.022	<.0001	0.023	<.0001	0.024	<.0001
UP			-0.047	0.233	-0.052	0.181	-0.048	0.220
HP			-0.034	0.538	-0.025	0.655	0.015	0.752
Fstat	341.6		132.94		106.94		132.55	
Adj R^2	0.095		0.1224		0.1227		0.122	
Obs	9706		11357		11357		11365	

P<0.01-Sig at 1%; 0.01< = P < 0.05 – Sig at 5 %; 0.05< = P < 0.10 – Sig at 10%

For illustration;

Model 2: PEF = 2.220 - 0.025*age + 0.020*height + 0.013*weight – 0.124*smoke – 0.334*dustyjob – 0.073*biofuel +0.082 * singlerm – 0.0.13*sepkit – 0.084*open air + 0.022*assetn – 0.047*UP – 0.034*HP