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RESEARCH PAPER

Health Damages from Air Pollution: Evidence from Opencast Coal Mining Region of Odisha, India

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Abstract: The present study examines the productive day's loss of local communities in the opencast coal mining region of Angul (Talcher) district in Odisha, due to respiratory illness, by using the dose-response function model. The productive day's loss is estimated in terms of restricted activities or work days lost, due to severe respiratory illness (RI), induced by air pollution. Health diaries are analyzed through the seasonal household survey to predict the likelihood of RI-related sickness (in terms of the restricted days) of the residents of the mining region (due to air pollution). Poisson and negative binomial regression are fitted for the purpose of count data analysis. The regression result confirms that there is a positive and significant relationship between the level of air pollution (respiratory suspended particulate matter (RSPM)/particulate matter less than 10 g/m3(PM10) and RI-related sick days, depicting that a reduction in air pollution level (PM10) may cause a reduction in expected number of RI-related sick days in the coal mining region. Further monetary welfare gain from avoiding the RI-related sick days are estimated for the population of Talcher coal mining area, Odisha.

Keywords: Air pollution, respiratory illness, health diaries, dose-response function, count data regression.

1. INTRODUCTION

Many developing economies with abundant mineral reserves are trapped in a low-level equilibrium, with abject poverty, unemployment, ill health, and poor education. This is the well-documented 'resource curse' or 'paradox of plenty' (Sachs and Warner 1997, 2001). Balancing efficient utilization of

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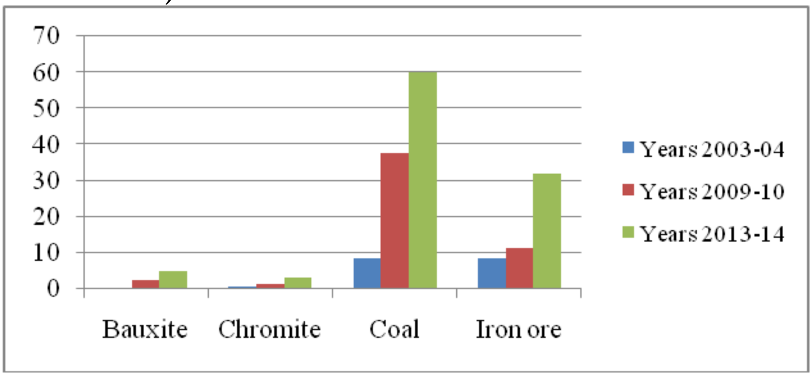
mineral resources with ensuring equitable and sustainable development and safeguarding the local environment and societal well-being is often a challenge.

Figure 1: Mineral Growth Trend in Odisha (in last 10 years) (Production in million tons)



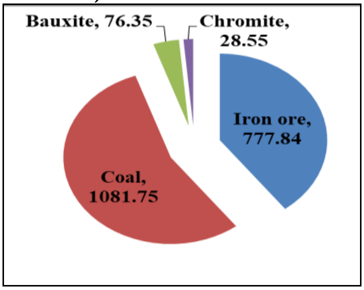
Source: Economy survey, 2014-15

In the post-liberalization period, many Indian states are encountering a voracious appetite for energy and infrastructure. The intense interstate competitions trigger the demand for energy and infrastructure, which is needed to attract investment to boost growth. This appetite has led to the rampant extraction and utilization of mineral resources in these states. Mining activities are often accompanied by a drastic jump in mineral rich pollution load (both air and water pollution), widespread soil degradation and forest cover loss (State of Environment Report 2008; David Stuligross 1999).

The state of Odisha is mineral-rich. In the post-reform period, Odisha and other mineral-rich states have been struggling to answer a difficult question: should they intensify their extraction of mineral resources in their quest for a high rate of growth at the cost of their environment?

Odisha is blessed with an abundance of mineral reserves — 24 per cent of India's coal reserves, 17 per cent of iron ore, 98 per cent of chromite, 51 per cent of bauxite, 35 per cent of manganese, and 92 per cent of nickel ore (Odisha Economic Survey 2014–15). The state has the second largest reserve of coal in India. The share of mining in Odisha's gross state domestic product (GSDP) has escalated significantly to 7 per cent of GSDP in 2014–15 (Odisha Economic Survey 2014–15). The state ranks first in country in terms of value of coal reserves and extraction. The state has witnessed an unprecedented increase in coal production from 8 million tons in 2003–04 to 60 million tons in 2013–14. Figures 1 and 2 depict the production recent growth trends of major mineral resources in Odisha. Coal alone accounted for 70 per cent of the mineral royalty received by the state for each of the past four years (Odisha Economic Survey 2014–15).

Figure 2: Production of Major Minerals in Odisha, 2013-14 (in Rs. lakh)



Source: Economic survey, 2014-15

Odisha is one of the richest biodiversity regions in South-East Asia (State of the Environment Report Odisha 2007). In terms of mineral deposits and production, the state occupies a vital position in the country (Murthy and Rao 2006; Economic Survey of Odisha 2014–15). The strong performance of the mining sector in terms of both production and value has thus resulted in a significant growth of the state's average GSDP (Economic Survey of Odisha 2014–15). The investment share of the mining sector in total outstanding investments makes Odisha the fifteenth highest recipient of foreign direct investment (FDI) among all Indian states. The mining revenue receipt has been steadily increasing over the past decade (Odisha Economic Survey 2014–15).

A report by the State of Environment (2008) has declared all the coal belts of the state most unsafe for human health and living conditions. The neighbourhood of the coal belt witnesses alarmingly high concentration of suspended particulate matter (SPM) and respirable particulate matter (RPM) exceeding the national standard level by several folds. Moreover, WHO (2002) suggests that coal mining process which release toxic pollutants can adversely affect the air quality in the surrounding environment.

Coal is an important source of fuel and power and is therefore critically important for the growth and development of a transition economy like Odisha's. Moreover, coal has the highest forward linkage with a number of other industries. Therefore, extraction of coal is an attractive option for a state for the creation of direct and indirect employment opportunities, foreign exchange earnings through FDI, generation of mineral royalties, tax revenues, etc. However, coal production is treated as 'dirty industry' as it is the most polluting natural resource (Elizabeth and York 2012; Michelle 2014). Apart from the direct impact of the occupational hazards of the coal miners, coal mining activities, particularly open cast coal mining, imposes highly negative environmental externalities (through air pollution, water pollution, contamination and loss of fertility of land, and forest loss and degradation) and health externalities (in terms of poor quality of health among the local communities, living in the proximity of opencast coal mining region). Mining and extraction activities create irreversible damages to the local environment, having long-run future consequences. From mining to combustion of coal, all the intervening processes release various toxic pollutants (such as RSPM (PM_{10})), carbon dioxide sulfur dioxide (SO_2) which adversely affect the air quality in the surrounding environment (WHO 2002). These huge amounts of wastages and pollutants (along with fly ash, coal dust, and heat) have dangerous health impact for the human beings living in the neighbourhood**.** Thus, from the policy perspective, or for state planning, it poses a serious challenge, in terms of a trade-off between the overall growth and development of the state vis-a-vis environmental degradation and health concerns of the local communities. Given the economic importance of coal, for a state like Odisha, forgoing the mineral extraction activities implies forgoing immediate opportunities for the entire state seems exorbitantly costly at the present stage of its development. As a consequence, the environment and health concerns of local communities in the mining region remain on the back burner.

Opencast coal mining leads to more severe air pollution than underground mining (Ghose and Banerjee 1995). All the mining processes, starting from drilling to transportation and screening, are the major sources of such emissions (Pathak *et al.* 2007). Air pollution in opencast coal mines is mainly due to the toxic emission of particulate matter and gases including methane, sulfur dioxide, and oxides of nitrogen. These air pollutants reduce air quality and ultimately affect people around mining areas (Nanda and Tiwari 2001). The major air pollutants produced by opencast coal mining are SPM and RPM (Sinha and Banerjee 1997; CMRI 1998). Mine fire is also considered as a major source of air pollution in some of the coalfields. The problems may have local, regional, and global impacts. Dust generated by opencast coal mining also affects agricultural productivity (Mishra 2008). Several research findings (Gupta 2006; Chowdhury and Imran 2010) show high concentrations of lower atmospheric pollution, especially RSPM(PM_{10}), adversely contribute to human morbidity, increase respiratory syndromes, and reduce lung functions. Longer term exposure to air pollution (PM_{10}) may lead to irritation, asthma, high blood pressure and heart disease**s** (Pope *et al.* 1995, 2007). High concentration of RSPM increase respiratory diseases such as chronic bronchitis and bronchial cases, while gaseous emissions contribute towards global warming, acid rain, and ground-level ozone besides causing health hazards to the exposed population (Pathak *et al.* 2007). Therefore, health risk and morbidity due to air pollution is high where opencast coal mining is predominant. Pattanayak *et al.* (2011) also observe that in Keonjhar, Odisha, local communities are vulnerable to diseases such as acute respiratory illness (RI), gastric, tuberculosis, and skin diseases, due to high exposure to toxic elements. All these health problems no doubt have economic costs arising from the expenses incurred in treating the diseases and productive days lost (Ostro 1994; Banerjee 2001).

Traditionally, opportunity costs of human health was interpreted solely on account of the individual's physical well-being without considering the environmental and social backgrounds around him (Rapport and Mergler 2004). From the 1970s, there has been a departure from the traditional belief, and 'health' is recognized as a precious asset in itself and an absolutely essential ingredient for human development and productivity (Grossman 1972). Good health with mental well-being is termed both a 'resource' and 'means' for stimulating economic development, and an outcome of economic development (Brundtland 2002); the WHO (2005) argues that 'quality of health' is related not only to freedom from diseases but also associated with a healthy and hygienic environment.

Therefore, this paper attempts to explore the linkages between health and the environment in the opencast coal mining area in Angul district of Odisha. This linkage paves the pathway for the significance of environmental quality in determining the quality of health and well-being. Given the enormous economic cost involved in terms of productive days lost and treatment of RI-related diseases caused by coal-mining activity, it is critically important to estimate the health impact of air pollution in the opencast coal mining region.

This paper is organized as follows. Section 2 reviews the literature. Section 3 explains the dose-response methodology that depicts the association between human health and air pollution. Section 4 presents the household survey design. Section 5 describes the econometric methodology. Section 6 presents the empirical estimation of RI-related sick days and discusses the regression results. Section 7 discusses the evaluation of the welfare gain of air pollution reduction. Finally, Section 8 presents the main findings and conclusions.

2. LITERATURE REVIEW

The seminal work by Grossman (1972) pioneered the formulation of a theoretical model of household production function. He analyses the demand for health by developing human capital model, where he suggests 'health' as a durable human capital stock and medical care as an important factor in its production. Cropper (1981) added pollution as a crucial ingredient and calculated the health damage reduction from the reduction in the air pollution level. Ostro (1994) suggests the a three-step method of calculating the health benefits of reducing air pollution. The first is to find out the dose-response relationship that shows the health outcome of air pollution. The second is to set the target group population, who are victimized, and exposed to the specific air pollution effect. The third is to calculate the change in air pollution level by implementing a specific pollution-reducing technique.

The more recent studies have attempted to explore a relationship between air pollution and the occurrence of illness by using dose-response and damage functions, while some economists have calculated the health damage cost of air pollution levels using one of three methods: cost-of-illness (COI), dose-response, and contingency valuation (Alberini *et al.* 1997; Ostro 1994; Krupanik 2000). In the case of South Asia, Murty *et al.* (2003) and Gupta (2008) calculated the health benefits from the reduction in urban air pollution level in the Indian states. Mishra (2012) estimated the damage to human health and agricultural productivity loss from pollution induced by coal-mining activities in Odisha. Chaulya (2003) shows that the annual average SPM and RSPM (PM_{10}) concentration in the Ib valley coalfield of Odisha exceeds the standards set in the Indian National Ambient Air Quality Standards (NAAQS) protocol for both residential and industrial areas. The problem is not limited to these areas alone; air ambient quality is critical in the state's entire mining belt.

The literature on estimating the morbidity and health impact costs are mostly confined to urban air pollution, vehicular pollution, etc. There are some studies on the health impact of air pollution in the cement industry (Bogahawatte 2008) and iron mining (Pattanayak *et al.* 2011), and of the occupational hazards (i.e., direct impact) of coal mining (Sarkar *et al.* 2004), but there are only a few studies to the best of our knowledge on the health impact of air pollution induced by opencast coal mining in Odisha (Mishra 2012; Singh *et al.* 2010; Hota and Mishra 2010). Most studies address the health concerns from air pollution and the pollution load in coal mining areas, but they do not address many important questions.

Therefore, this study tries to bridge the research gap by examining the association between the air pollution level and negative health outcomes (we consider RI for this study)[1] in the opencast coal mining region (Angul-Talcher) of Odisha. This study also tries to analyse the economic impact of

[1] RI includes all the common acute syndromes of respiratory diseases such as: bronchial asthma, cough with mucus, and sputum production, respiration allergy to dust, allergic cough, running nose, headache, flu, and fever, chest tightness, pain, and acute bronchitis. These symptoms are identified as commonly reported respiratory illness after consulting the specialist doctors from the Mahanadi Coal Field Hospital, located in the study region.

Table 1: Categorisation of Ambient Air Quality Status with respect to criteria pollutants based on prescribed standard and exceedance factor

Pollution level	Residential/Industrial	
	RSPM(PM_{10}) ($\mu g/m^3$)	$PM_{2.5}$ ($\mu g/m^3$)
Low (L)	0-30	0-20
Moderate (M)	30-60	20-40
High (H)	60-90	40-60
Critical (C)	>90	>60

Source: State Pollution Control Board, Bhubaneswar

negative health effects by considering the loss of wages of productive days for the study region.

We raise some unanswered questions. (1) To what extent does the coal mining activities contributed to the health-related well-being of the local community in the mining region and to their environment? (2) Does the critical ambient air quality near the opencast coal belt matter to the health of the neighbouring community? (3) How do the socio-economic factors affected the health stock of the local communities in the neighbourhood of coal mining areas? (4) How many productive days are lost by the local communities due to RI related diseases on account of such negative externalities ?

Against this backdrop, the study area is located in a coal mining district Angul of Odisha, in the eastern part of India. The state has two coalfields namely- Talcher coalfield (in Angul district) and lb River coalfield (in Jharsuguda district).The coalfield of Ib valley is comparatively new compared to that of Talcher coal field(Directorate of Mines, Government of Odisha, Bhubaneswar). The older the coal mines project, the more is its environmental impact. The numbers of active opencast coal mine projects are also larger in Talcher coal field area than the IB valley coal field. As per the latest report by Central Pollution Control Board (CPCB 2009) on Comprehensive Environment Assessment of Industrial Clusters, Talcher coal filed region of Odisha has secured seventh position as one of the most critically polluted industrial cluster in India.[2] Keeping in mind of all these perspectives we select the Angul-Talcher coal mining region as our study region[3].

[2] The concentration of PM_{10} in air is very high for the study region which often exceeds the prescribed level (by Central Pollution Control Board) by two folds. See the table no (1) and (2) for detail about the severity of air pollution.

[3] See Figure 3 for the district wise extraction and value of coal in Odisha in recent year.

Table 2: Ambient Air Quality of the study region 2015-16

Month	Station 1 (MCL)		Station 2 (TTPS)		Station 3 (NALCO Nagar, Angul)		Station 4 (Industrial Estate, Angul)	
	Average		Average		Average		Average	
	RSPM (PM_{10})	$PM_{2.5}$	RSPM (PM_{10})	$PM_{2.5}$	RSPM (PM_{10})	$PM_{2.5}$	RSPM (PM_{10})	$PM_{2.5}$
January	171	130	154	122	137	98	137	94
February	186	99	165	115	117	80	108	80
March	161	87	136	76	129	65	118	74
April	177	105	91	53	108	57	92	51
May	149	93	123	79	97	80	95	50
June	140	87	71	44	78	38	84	47
July	126	72	56	34	80	47	88	53
August	100	57	61	34	79	39	65	49
September	87	39	70	51	100	49	96	57
October	133	48	95	75	91	52	98	54
November	135	75	126	68	105	57	105	54
December	134	79	164	86	107	54	105	56
Average Annual	**140**	**81**	**111.08**	**69.75**	**102**	**57**	**99.25**	**60**
Source: CPCB (2009)								

3. DEFINING THE RELATIONSHIP BETWEEN HUMAN RESPIRATORY HEALTH AND AIR POLLUTION: DOSE-RESPONSE FUNCTION

Often, the relationship between air pollution and premature mortality is studied by using time-series analysis of daily observations of number of deaths and the pollution level. These studies capture the effects of the short-term exposure to pollution on the probability of dying. But it is expected that people, who are in a weak physical state or who have a history of chronic diseases are more susceptible to contact recurring diseases due to the high concentration of pollution in the environment and are therefore supposed to be the most vulnerable. These types of exposure can be captured through the 'dose-response function'. If there is a cause of high concentration of pollutants in the surrounding environment, then it may trigger some negative health outcome (i.e., negative externalities of environmental pollution) as its effect. This association between cause and effect has been known as 'dose-response function'.[4]

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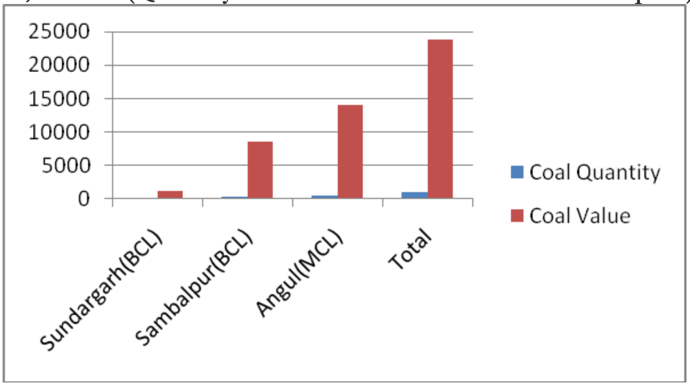
[4]See Ostro (1983, 1987, 1994), who estimated the 'Dose-Response Function' to find out the impact of air pollution on morbidity and found that PM_{10}, affect both the restricted activity days and work days lost.

This function captures a range of responses towards the respiratory illness of different individuals due to different degree of outdoor pollutants, when other confounding socio-economic factors and the level of indoor pollution are controlled. This function therefore relates the importance of a 'Dose' (that is the intensity of air pollution to which the local people are exposed) to the 'responsiveness' of the individuals (the response may be any kind of morbidity due to the respiratory diseases, stress, and even death or mortality). The degree of impact can be captured as the proportion or the days of sickness or restricted activity days due to respiratory illness syndromes (H).This method estimates the partial derivative (or the slope of *b*) of 'Dose-Response' function as given in the following equation (1). The purpose is to calculate the marginal effect of a change in occurrence of a given health outcome related to a change in air ambient quality (A) with other confounding factors.

Figure 3: District wise break-up of extraction and value of coal in Odisha, 2013-14 (Quantity in lakh MT and value in crore of rupees)



Source: Economy survey, 2014-15

The next step by Ostro (1994) is to calculate the numbers of people who are supposed to be exposed to the particular air pollution effect (i.e. POPi).Then how many productive days (restricted activity days or sick days), they are losing because of the exposure. Finally, the last step is to calculate the welfare gain due to a unit change or reduction in ambient air quality (dA).

Thus the dose-response function can be expressed as (following Ostro 1994):

$$dH_i = b * POP_i^* dA \qquad (1)$$

Where, dH_i = change in individual's risk of health outcome i

b = slope from the 'dose-response' function.

POP_i = targeted population at risk of health impact i
dA = change in ambient air quality under consideration

4. SURVEY DESIGN

The present study is based on the primary survey at the household level, though pollution data are collected from the secondary sources such as State Pollution Control Board, Odisha and Regional Pollution Control Board, Angul. To understand the severity of air pollution on the health outcome of the local residents we first conducted a pilot survey followed by five rounds of group discussions during September 2015. Baseline information was collected from that pilot survey from some randomly selected households in the vicinity of Mahanadi Coal Field Limited. The baseline information did confirm the severity of health problem in the region. To capture the exposure of air pollution on human health (for those who are residing near the coal field area) through 'dose-response' method, we required background information on the health status of individuals residing in the study region along with other environmental and socio-economic information. The pilot survey helped us to design a well-structured questionnaire for the final survey. We conducted the survey during September 2015 to January 2016, involving (210) households of the 10 neighbouring villages, of Angul-Talcher opencast coal mining region of Mahanadi Coal Field Limited (MCL). Following Krupanick (2000), Gupta (2008), Murty et al. (2003), Adhikari (2012) and Imran et al. (2010), the survey kept track of weekly health diary of the selected households for six weeks extended over two seasons. We followed *two stage stratification,* for selecting sample (following Gupta 2006 and Adhikari 2012). The reason for following a two stage stratification sampling procedure is to capture precisely the local people's exposure to air pollution and the consequent adverse health impact. In the first stage of stratification, the villages within a four-kilometre radius from the air pollution monitoring station were identified (and a total 10 villages were selected. We then randomly selected 21 households from each village. Thus a total of (21 x 10 = 210) households from 10 villages and an aggregate of 855 members were surveyed[5]. Out of 855 household members 254 members were suffering from RI symptoms during the first round of the survey. Given the seasonal

[5] The sampling framework takes into account the randomly selected households from each of the 10 villages, which are located within a stipulated area i.e., 4 km radius surrounding the station. So the selection bias is likely to be minimum and therefore can be comfortably ignored. Here proximity is used to identify the neighbourhood areas which are very close within the radius of 4 km from the opencast coal mines.

differentiates in air quality levels, we collected health diary information on 254 household members repeatedly for six weeks during two different seasons (i.e. October or post-monsoon and December or winter). The health diaries covered the RI-related health status, of mitigating expenditure, chronic illness etc. Therefore the survey resulted in a pooled data, containing 1524 (= 254 x 6) observations. But by using the Stata software 12.0, we found only 932(restrictive sample) observations having RI diseases, sick days, and mitigating expenses over the entire 6 weeks. Given that the present study is focused on the number of RI-related sick days, so a total of 932 observations on the basis of availability of full information could only be taken for empirical investigation.

5. EMPIRICAL ESTIMATION OF RI-RELATED SICK DAYS

Our goal is to estimate the number of sick days or restricted activity days of a person suffering from respiratory diseases. This dependent variable counts the duration of sickness episode which is related to the particular respiratory syndromes (associated with air pollution) based on one week recall period[6].The dependent variable counts how many days in a week (based on one week recall period), an individual is unable to work or restricted from other activities due to respiratory illness. As our dependent variable i.e., 'sick days' is finite number of non-negative integers (small discrete values, say 0 1 2, 3, 4, …) or count values, assuming 0 values in several observations, we need a probability distribution that takes care of this count data. We used the Poisson and Negative Binomial regression to model the count outcomes i.e., the negative health impacts of air pollution (captured by the number of restricted activity days) as experienced by the respondent in a given time period.

Given that Poisson regression is the starting point of count data analysis, we initially fitted the Poisson regression to the number of sick days by using the method of Pseudo Maximum Likelihood Estimation or Quasi-Maximum likelihood estimation. It is possible to write the probability of number of sick days(Y) for a respective individual, using the Poisson regression model as:

$$\text{Prob.}\left(Y_{it} = \frac{y_{it}}{x_{it}}\right) = \frac{\lambda_{it} y_{it} e^{-\lambda_{it}}}{y_{it}!}, y_{it} = 0,1,23,\ldots 7\ldots \quad (2)$$

[6] For the primary survey we collected information regarding the prevalence of RI-related diseases and the mitigating expenditure incurred by the household and therefore we set the recall period of one week. This is deliberately done to extract correct information on the mitigating expenditure data.

where $\lambda_i = e^{\beta x}$

Here y_{it} denotes the RI-related sick days or restricted activity days (related to air pollution level) for an *individual i* at time period *t*. '*e*' is the exponential function of $y_{it}\lambda_{it}$, the mean value of the number of sick days due to pollution. β is the vector of regression coefficients while x_{it} is the vector of independent variables. And u_{it} is the unobserved error term that may affect the individual health stock.

The estimated mean value is therefore: $\hat{\lambda}_t = e^{\hat{\beta}x}$. A log transformation gives the equation: $\ln \hat{\lambda}_i = \hat{\beta}x$

As the count data variance usually exceeds the mean, the Poisson model has its limitation arising from the property of equi-dispersion. Alternatively we also run the negative binomial model (NBM) as an alternative model which accounts for the overdispersion in count data, when the conditional variance surpasses the conditional mean. The only difference between two is that NBM has an ancillary parameter (α) to model the overdispersion.

5.1. Choice Variables

The vector of explanatory variables comprises of daily PM_{10} data obtained from the nearest air pollution monitoring station from the respondents' residence. The study has narrowed down the 'daily (PM_{10})' as the single-most important indicator for air pollution in the coal belt, as the exposure to PM_{10} is considered to be most damaging impact on respiratory health (Gupta 2006; Chowdhury and Imran 2010).[7]

We control for a bunch of variables[8] including pre-existing illness (from previous week), chronic diseases,[9] exposure to outdoor pollution or coal

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[7] Several research findings show high concentrations of lower atmospheric pollution especially RSPM (PM_{10}) contribute to human morbidity, increase respiratory syndromes, and reduced lung functions (Gupta 2006; Chowdhury and Imran 2010). The secondary data on air pollution shows that in open cast coal mining areas in Odisha, the PM_{10} level is alarmingly high and often exceeds the national prescribed level by Central Pollution Board by several fold.

[8] Table 3 defines the main variables and its original question which were asked at the time of survey.

[9] When one individual has been suffering from the diseases like asthma, blood pressure, heart diseases, and tuberculosis for more than 1 year, then that person is to be treated to have a chronic illness. The chronic disease of an individual describes his health stock. If an individual has been suffering from a chronic disease then it is expected that he is more vulnerable to air pollution exposure and is therefore supposed to have higher number of

Table 3: Example of Variables and Categories Used

Coal mining externalities (Due to air pollution)	Defining variables	Original Questions
Health	Adult outdoor exposure and workplace information	Based on the questions regarding workplace location, number of working hours/day, affected by coal fumes/dust, loss of income/day if work lost due to RI related sickness
	Children outdoor exposure	Based on questions regarding number of hours spent daily in school/college/other places and therefore whether exposed to coal fumes/dust or not.
	Occurrence of respiratory illness	To capture the respiratory health status- different types of RI related diseases and its frequency of occurrence in daily and weekly basis, based on the recall period in the previous week and in last year were asked.
	Health effects	Status of health with the level of air pollution
	Health cost	Income lost due to loss of productive/restricted workdays
	Annual income	Income calculated from different sources
	Per capita income	Households total income from different sources divided by the number of household members
	Indoor pollution	Captured by the questions on the nature of fuel use, use of chimney/exhaust fan in kitchen, disposal of solid waste?
	Ownership status	Different types of assets from different sources

Source: Author's own survey schedule

illness related sick days. This is used as control variable in our econometric analysis, which captures the occurrence of chronic illness among the individuals. It assigns a value '1' if the respondent reports a chronic diseases (as mentioned above) otherwise it assigns a value '0'.

Table 4: Descriptive Statistics of Independent Variables

Variable	Description	Obs.	Mean	Standard Dev.	Minima	Maxima
PM_{10}	Average Weekly PM_{10} (ug/m3)	6	148.68	13.79	132.5	167.5
Age	Age of Household Members in Years	932	38.40	20.36	1	82
Edu_inyears	Education in Years of Schooling (for illiterate)	932	6.58	4.08	0	15
HH_size	Household Size	210	4.06	1.15	1	8
HH-Income	Household Income in Rupees.	932	19062	12564	1500	80000
PCI	Per capita Income in Rupees. (Household Income divided by Number of household Members)	932	4806	3094.07	700	20000

Own source: Primary Survey, 2015-2016

dust,[10] smoking etc., to avoid overestimation of pollution exposure on health effects of the respondents. Besides these individual characteristics (like age, gender, education, awareness about adverse health effect of pollution, per capita income level, and exercise habits) and household characteristics (household size and medium of cooking, fuel or indoor

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[10]As discussed, coal is one of the most polluting natural resources (because it emits toxic pollutants such as carbon dioxide, sulfur dioxide, respiratory suspended particulate matters etc. to atmosphere). The brittle nature of coal creates coal dust in the coal mining activities including loading unloading, transportation etc. In the open cast coal mining neighbourhood villages, the suspended coal dusts often create haze in the atmosphere which often interrupts visibility. Given these facts it is evident that regular exposure of the air borne contaminants due to coal and coal dust may trigger respiratory illness. It is anticipated that more outdoor exposure may increase the probability of illness. The exposure to coal dust is a dummy variable which assigns 1 if the representative individual is exposed to outdoor coal dust (or stay in outdoor more than 1 hour a day), otherwise it is 0 (zero).

Table 5 Poisson Regression Model

Dependent Variable (sick days)	**Poisson**	
Independent variables	Coefficient(P-value)	Standard Error
PM_{10}	0.0059**(0.001)*** **	0.1907
Age	-0.0004(0.887)	0.0033
Age square	6.2307(0.989)	0.0004
Gender	-0.061(0.178)	0.0454
HH size	0.021(0.191)	0.0156
Exposed_coaldust	-0.057(0.178)	0.0426
Awar_polutnhelth	**-0.139(0.001)*** **	0.0436
Asthma_cronic	**0.123(0.001)*** **	0.0378
B.P	-0.004(0,383)	0.0478
Indiv_smoking	**0.105(0.079)* **	0.0604
Fuel_coaldumy	**0.071(0.081)* **	0.0413
Prevsweek_ill	**0.123(0.001)*** **	0.0370
Prevsweek_expend.	-0.052(0.146)	0.0361
Exercise	-0.028(0.539)	0.0466
PCI	0.042(0.215)	0.0343
Constant_	**-3.260(0.001)*** **	0.9934
Log pseudo likelihood	**-1914.7761**	
Wald ch^2(df)	**(15) 95.28**	
Prob.>chi^2	**0.000**	
Pseudo R^2	0.024	
No of observation	932	

(***, ** and * indicate significance at 1%, 5% and 10% level respectively)

pollution), that may affect the health outcomes are controlled in the regression analysis.[11]

[11] We have presented the descriptive tables of independent variables in table 4, which includes only the continuous and categorized independent variable's descriptive statistics. We have not included some independent variables viz., gender, chronic disease, exposure to coal dust, or outdoor pollution, smoking habit, awareness regarding effect of pollution on health, coal as a fuel, exercise and previous week illness and illness related expenditure's descriptive statistics as these variables has taken as dummy variable in regression model.

6. REGRESSION ANALYSIS

The regression result of the Poisson and NBMs are given in Tables 5 and 6, which display the regression coefficients, standard errors, and probability values (z>p) for each explanatory variable.

In table (5) and (6), both the regression model (Poisson and NB) present approximately similar results, because the 'α' value (the parameter which accounts for overdispersion) is very small (i.e., - 0.0103) in NBM. The only difference is that the Poisson model gives the robust standard error (as it is based on pseudo maximum likelihood method and the NBM accounts the overdispersion as it has one ancillary parameter i.e., α.

The regression results confirms our hypothesis that there is a positive and significant relationship between the level of air pollution (RSPM/PM_{10}) and RI-related sick days. The coefficient of PM_{10} (0.0059) is positive and statistically significant at 1 per cent level of significance (p-value is 0.001 or equivalently t-value is 4.22) in the Poisson model. The positive coefficient of pollution variable depicts that a reduction in air pollution level (PM_{10} level) will cause a reduction in expected number of RI-related sick days. The coefficient of awareness regarding pollution related health impact is negative and significant at 1 per cent level; showing a decrease in sick days due to the rise in awareness level. The coefficient of chronic diseases asthma is positive and significant at 1 per cent level, thereby presenting an increase in sick days as the chronic asthma increases. The other socio-economic and control variables such as individual smoking habits, coal-fuel[12] and illness in previous week have positive coefficients as expected and are also statistically significant.[13]

The coal as a daily household fuel has been controlled for indoor air pollution. This variable is statistically significant and positive impact on aggravating the respiratory illness and its related sick days. The individuals who have active smoking habits are more susceptible to the exposure of air pollution and thus respiratory illness related sick days increases for them. The presence of respiratory illness in the previous week among the individual increases the risk of experiencing more RI-related sick days.

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[12] The frequency of using 'coal' as a cooking fuel contributes to the level of indoor air pollution. The study assumes it as a dummy variable giving the value 1 if a representative household uses coal for their cooking regularly. Here, we consider if a household uses coal as a fuel for cooking more than 20 times in a month, then we take the value 1 and it takes 0 otherwise.

[13] We have checked the multicollinearity and heteroscedasticity test for the model after running the regression and found these problems among the independent variables are not a serious concern for the model. The Wald chi2 (15) is 95.28 with p-value 0.000, which indicates the model is significant as a whole.

Table 6 Negative Binomial Regression Result

Dependent Variable (sick days)	Negative Binomial	
Independent variables	Coefficient(P-value)	Standard Error
PM_{10}	0.0059 __(0.000)***__	0.1942
Age	-0.0004(0.891)	0.0034
Age square	4.5107(0.992)	0.0004
Gender	-0.061(0.186)	0.0463
HH size	0.021(0.200)	0.1595
Exposed_coaldust	-0.057(0.185)	0.4341
Awar_polutnhelth	__0.139(0.001)***__	0.0444
Asthma_cronic	__0.123(0.001)***__	0.3855
B.P	-0.004(0,390)	0.4875
Indiv_smoking	__0.105(0.084)*__	0.6159
Fuel_coaldumy	__0.071(0.091)*__	0.0421
Prevsweek_ill	__0.123(0.001)***__	0.0377
Prevsweek_expend.	-0.052(0.151)	0.3686
Exercise	-0.028(0.555)	0.0475
PCI	0.042(0.220)	0.0349
Constant_	__3.266(0.001)***__	1.0110
Lnalpha :	-4.567SE(1.4013)	
Alpha:	0.0103SE (0.1455)	
LR test of alpha=0 Chibar2(01) Prob.>chibar2	54.43 (0.000)	
Log likelihood :	-1914.5084	
LRchi^2(df):	(15) 85.98	
Prob.>chi^2	0.000	
Pseudo R^2	0.022	
No of observation	932	

(***, ** and * indicate significance at 1%, 5% and 10% level respectively)

7. WELFARE GAIN (IN MONETARY TERMS) OF THE REDUCTION IN RI-RELATED SICK DAYS

To estimate the monetary benefits from the reduction in RI-related sick days, we calculate the marginal effect from the Poisson regression. Marginal effect defines the reduction in RI-related sick days due to the fall in PM_{10} levels in air.

Following Gupta (2006), Chowdhury and Imran (2010) and Adhikari (2012), monetary benefits from reduction in RI-related sick days can be expressed as:

$$\beta * \lambda * \Delta PM_{10} * \frac{365}{7} \quad (3)$$

Where β is the coefficient value of PM_{10} from Poisson regression model ($\beta = 0.0059$)

λ is the predicted value of (H) or RI sick days from the Poisson model ($\lambda = 0.0205$)

($\lambda = 0.0205$, is the predicted value of sick days from the Poisson model, which is calculated by the help of post-regression analysis command in Stata-12.0)

ΔPM_{10} is the change in the level of PM_{10} from the current to the safe standard prescribed level, (the average current level PM_{10} in two seasons is 159 $\mu g/m^3$ and the prescribed standard level by Odisha Pollution Control Board (OPCB) is 90.4 $\mu g/m^3$ for residential area.)

($\beta * \lambda$) is the marginal gain from Poisson estimation or ($0.0059 * 0.0205 = 0.00012$)

The Poisson regression result shows that 1 $\mu g/m^3$ reduction in PM_{10} results in a marginal benefit of 0.00012(days) for a representative household member in a week. In order to calculate the welfare gain in sick days for a representative household member by reduction in PM_{10} to a safe level, we have to multiply the marginal benefit value by ΔPM_{10} i.e., $0.00012 * 68.6 = 0.00823$ as gain in reduction in sick days for a representative household member. The annual benefit in monetary terms or welfare gain can be calculated by multiplying this value 0.00823 with the $\frac{365}{7}$ i.e., 0.4292 as annual monetary benefit for reduction in sick days due to reduction in PM_{10} level or improvement of PM_{10}.

Putting the values in equation (3)

$0.0059 * 0.0205 * 68.6 * 52.14 = (0.43)$ days per year for a representative household member.

Here: $\beta = 0.0059$, $\lambda = 0.0205$, $\Delta PM_{10} = 159\ \mu g/m^3 - 90.4\ \mu g/m^3 = 68.6\ \mu g/m^3$ and $\frac{365}{7} = 52.14$.

The calculated average wage (per monthly) of working individual is Rs. 275 from working group sample from the survey data. Thus the annual monetary gain for a representative household member is $0.43 * 275 =$ Rs.118.25 by avoiding the RI-related sick days due to reduction in PM_{10} level. By extrapolating for the total population of Talcher coal mining area, the monetary welfare gain from avoiding the RI-related sick days are estimated as Rs. 64, 95,51,5.66 per annum.

However our study presents lower bound estimation of monetary welfare gain (of health improvement) from the reduction in air pollution in the opencast coal mining of MCL of Talcher area. The study has the limitation of not capturing the averting expenditure of air pollution and the opportunity cost of time spent for seeking care. It poses a serious constraint to gather information on these variables from the survey because of the heterogeneity of the respondents (covering children, women, and old persons other than the working people). Moreover the region is endowed with some active public health centres run by MCL, offering some basic health services to the local community. The out of pocket expenditure which was captured during the survey was mainly the expense incurred by the residents from the private consultation over and above the free services they can avail from primary healthcare centres (PHC). The compulsion to visit the private practitioner was mainly due to congestion, long waiting time, recurrence, lack of doctor, non-availability of medicine etc., as reported in the survey.

8. CONCLUSION

For developmental processes, the economic importance of coal is undoubtedly very high, being the cheapest source of energy. However coal is the most polluting natural resource; from production to combustion it leads to the emissions of various harmful gases including methane (CH_4), sulfur dioxide (SO_2), and nitrogen oxides (NO_x), carbon monoxide (CO), particulate matter, various toxins, etc. Besides coal dust, coal wastes, and coal particles are produced during the mining process, soot is released during the transportation of coal. It is evident from various studies that all these pollutants can cause severe and potentially deadly respiratory and lung problems, and cardiovascular diseases. Thus, apart from the direct impact of the occupational hazards of the coal miners, coal mining activities (particularly opencast coal mining), imposes highly negative environmental externalities (through air pollution, water pollution, soil contamination and fertility loss and forest loss and degradation) and health externalities (in terms of poor quality of health among the local communities, living in the proximity of opencast coal mining region). Although there is huge economic cost involved in tackling these environmental and health externalities,[14] it is seldom addressed seriously at the policy level or in the

[14] See Epstein *et al.* (2011, 92). At the Center for Health and the Global Environment, Harvard Medical School, Dr. Paul Epstein and others found that accounting for the full

implementation stage. Thus the pricing of coal involves huge cross-subsidies in India from the unaccounted environmental and health damages. Even the conservative attempt of imputing these negative externalities in the pricing of coal would have increased the price of coal several folds.

This primary concern of this paper has been on the impact of air pollution on respiratory health (in terms of their number of sick days or restricted days due to RI) among the residents of some coal mining regions of Odisha. The attempt is to capture the partial impact of air pollution (triggered by coal production) on respiratory health damages. Given that the level of PM_{10} is always at an alarming level in the Angul-Talcher coal mining region, it is natural to expect that the respiratory health outcome would be very pervasive and critical in the proximity of the coal field. It is evident from the literature that the critical air pollution level (particularly concentration of PM_{10} in air) affects the respiratory health status (lung and chest problems, cough, bronchial asthma, bronchitis, TB and other lung related diseases) of the residents in the proximity of the coal field.

Our empirical exercise predict the likelihood of RI-related sickness (in terms of their restricted days/sick days) of the residents near the open cast coal mines (due to air pollution). We find there is a strong and direct relation between acute respiratory disease related sick days or restricted activity days and the level PM_{10} (air pollution) in Angul-Talcher coal mining area. The positive value of the coefficient of pollution variable depicts that a reduction in air pollution level (PM_{10} level) causes a reduction in expected number of RI-related sick days. We find that a representative individual in the Angul-Talcher region can save 0.43 days or Rs. 118. 25 by avoiding the RI-related sick days, if there is a reduction of 68.6 $\mu g/m^3$ of PM_{10} per year. This is calculated by taking the difference between the average current level of PM_{10}in the two seasons (i.e. 159 $\mu g/m^3$) and the standard level (i.e., 90.4 $\mu g/m^3$) as prescribed by the OPCB. Thus the monetary welfare gain from avoiding the RI-related sick days for the entire population of Talcher coal

costs of coal would double or triple its price. The study, released in the Annals of the New York Academy of Sciences, tallied the economic, health, and environmental costs associated with each stage in the life cycle of coal—extraction, transportation, processing, and combustion—and estimated those costs, which are borne by the public at large, at USD 175–500 billion annually. Air pollutants from combustion accounted for USD 187.5 billion, mercury impacts as much as USD 29.3 billion. The report estimated the public health burden in Appalachian communities at USD 74.6 billion a year, and that death, injury, and increased healthcare costs constituted much of the impact. The study discussed several other impacts that are not easily quantified: coal mining and processing releases heavy metal toxins and carcinogens into water supplies; coal miners die at work or are injured; and coal mining societies are impacted.

mining area are estimated to be Rs. 64, 95,515. 66 per annum. Although the study derives the lower bound estimates of monetary gain due to the reduction in air pollution, the figures bears some serious policy concerns.

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