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Gold mining pollution and the cost of private healthcare

The case of Ghana

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Abstract: To attract greater levels of foreign direct investment into their gold mining sectors, many mineral-rich countries in sub-Saharan Africa have been willing to overlook serious instances of mining company non-compliance with environmental standards. These lapses in regulatory oversight and enforcement have led to high levels of pollution in many mining communities. The likelihood is high that the risk of pollution-related sicknesses, such as skin infections, upper and lower respiratory disorders, and cardiovascular diseases, will necessitate increasingly high healthcare expenditures in affected communities. In this study, we propose and estimate a hedonic-type model that relates healthcare expenditure to the degree of residents' exposure to mining pollution using data obtained on gold mining in Ghana. The empirical results confirm that, after controlling for factors such as current and long-term health status, increased mining pollution leads to higher healthcare expenditure.

Keywords: mining pollution, healthcare expenditure, hedonic analysis, Ghana
JEL classification: Q32, Q38, Q53

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1 Introduction

Studies have shown that gold extraction and processing can significantly degrade natural environments and, with that, human health (Saldarriaga-Isaza et al. 2013). Some of this environmental and human damage can be irreversible (see e.g. Naicker et al. 2003). In Ghana and elsewhere in Africa, gold miners, both large- and small-scale, routinely discharge toxic chemicals such as mercury, cyanide, and arsenic and their harmful compounds into water bodies, exposing workers and residents to a range of health risks including lower respiratory tract infections, cardiovascular disease (Mergler et al. 2007), skin infections, and cancerous infections (Amegbey and Adimado 2003; Adei et al. 2011).[1] In addition, the use of heavy machinery in extracting the ore, coupled with the surface mining techniques commonly employed by miners in many developing countries, generates substantial dust which can cause or exacerbate respiratory disorders (ILO 2005). Yet, such damages are rarely accounted for by the miners. It has been argued that the strong desire to earn foreign exchange from mineral extraction has weakened the resolve of resource-rich African states to pass, or enforce, mining-related environmental regulations (McMahon 2011).

A number of studies have been undertaken on the health impact of gold extraction (see, e.g. Graff Zivin and Neidell 2013; Currie et al. 2014), but there is little research quantifying the welfare impact of mining externalities, especially in Africa. To help fill that gap, this study presents a simple hedonic-type model that links private healthcare costs (both preventive and curative) to exposure to gold mining-related pollution, and empirically verifies the model using data from Ghana. Our results support the hypothesis that, all else being equal, healthcare expenditure is higher if a household is closer to a tailing site.

Furthermore, using anecdotal evidence about the relationship between distance to the tailing site and concentration of nitrogen dioxide (NO_2), which is considered a surrogate for other toxic substances released during mining activities (WHO 2006), we are able to directly link pollution concentration to residents' willingness to accept (WTA) compensation due to the pollution.[2] Other statistically significant covariates of the healthcare expenditure model include household income and age of the household head, both of which positively impact the dependent variable, and subjective health status and the variable 'health insurance paying a greater portion of healthcare bills', both of which had a negative impact.

2 An overview of gold extraction and extraction externalities in Ghana

Ghana has produced and exported gold since the fifteenth century (Akabzaa and Darimani 2001). Before the nation's independence, gold mining was controlled and restricted to profit the European companies. After independence, however, increasing government involvement reduced foreign control of the sector. Over time, the mining infrastructure suffered neglect and the mines were operated inefficiently leading to decline in profits in the late 1960s through the dawn of the 1980s (Akabzaa and Darimani 2001). A national decision was made in the early 1980s to attract substantial injections of international capital (primarily European and more recently North American) into the sector.

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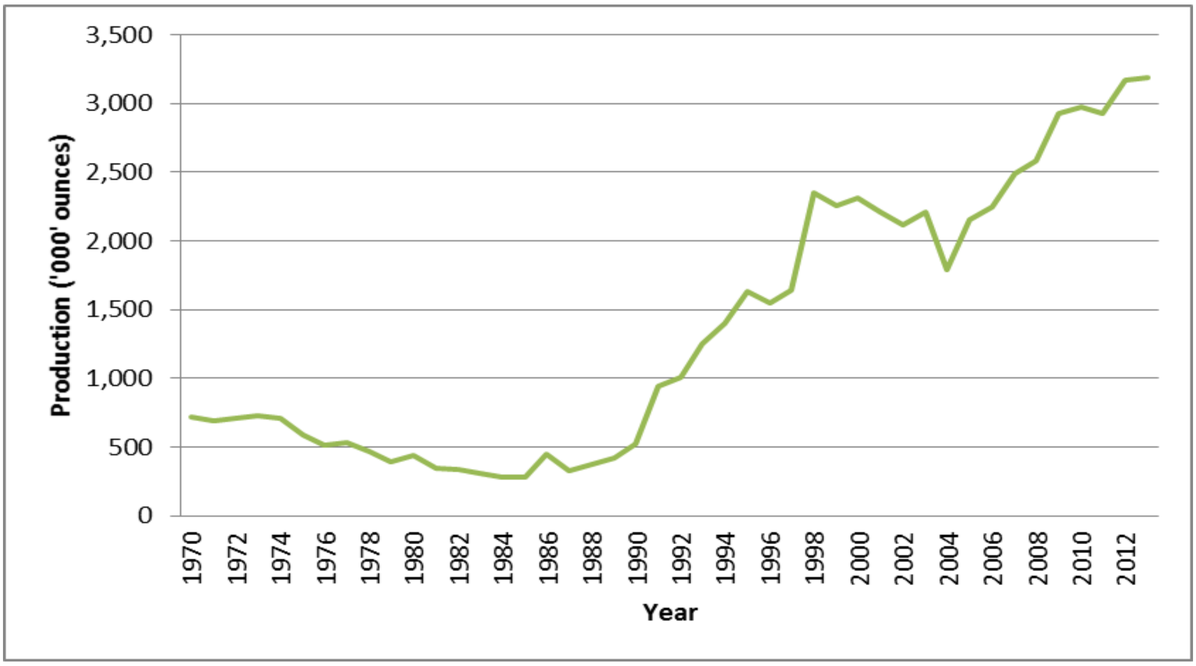
[1] There is substantial evidence of heaped waste materials at mining sites in Ghana resulting in the release of toxic chemicals into the environment (see e.g. Akabzaa et al. 2007; Essumang et al. 2007; Yidana et al. 2007; Armah et al. 2010)

[2] It is noteworthy that supply of health care services does not vary across concentric zones around the tailing sites.

In order to make the mining sector more attractive to foreign investment, Ghana's Minerals and Mining Law was passed in 1986, offering generous capital allowances and concessions such as delayed or reduced income taxes. The specific fiscal incentives granted include a significant reduction in corporate tax rate, permission to write off three-fourths of capital investment against taxes in the first year and one-half for subsequent years, a reduction in royalty rate from 6 to 3 per cent, and the scrapping of all other duties and taxes (Akabzaa and Darimani 2001). The government also permitted companies to use offshore bank accounts for the servicing of loans, dividend payments, and expatriate staff remuneration. Furthermore, the mining companies were allowed to retain between 25 and 45 per cent of gross foreign exchange earnings from minerals sales in company accounts.

In response to these incentives, and with rising gold prices, between 1985 and 1990 alone 11 new mining companies became active in the sector, with foreign participation representing an investment total of US$541 million. Overall production gradually recovered and by 1992 Ghana's gold production had surpassed 1 million fine ounces (i.e. 31,103kg), significantly up from 327,000 in 1987 (see Figure 1).[3] Output continued to rise, reaching 3.2 million fine ounces in 2013. This output expansion, significantly, came on the heels of continued investment in the sector, which totalled approximately US$6.9 billion between 2000 and 2011.

Figure. 1: Trends in gold production in Ghana 1970–2013 ('000' ounces)



Source: Drawn using data from Ghana Chamber of Mines (2008, 2011, and 2013).

There is little denying that the macroeconomic gains made by Ghana's mining sector since 1986 have benefited the economy in terms of exports (see e.g. Akabzaa 2009; Gough and Yankson 2012). It is, however, argued that mining activity made only a marginal contribution to GDP, generated limited job opportunities, especially for the individuals in mining communities, and took away farmlands thereby worsening the livelihoods of individuals within the mining communities (Anyemedu 1992; Essumang et al. 2007; Armah et al. 2012; Boateng et al. 2012; Hilson and Garforth 2012; Ferring et al. 2016).

[3] A fine ounce (troy ounce) is equivalent to 31.1034768 grams.

Throughout Ghana, the environmental and health effects of large-scale mining activity have been negative, potentially very strongly so (Hilson and Nyame 2006). Decades of laissez-faire and even reckless mining, tolerated by a lax regulatory regime focused more on output than on health, have resulted in increased concentrations of heavy metals and other pollutants in numerous water bodies and soils (Antwi-Agyei et al. 2009; Boateng et al. 2012; Armah et al. 2012; Bempah et al. 2013). This has been accompanied by massive deforestation, the forced relocation of entire communities due to mining activities, and the associated outright destruction of a wide range of cultural resources (Hilson 2006; Britwum et al. 2001). Several reports have been made, both officially and anecdotally, of instances of cyanide mismanagement in gold mining areas, resulting in the widespread contamination of freshwater sources, fish populations, and the crops on which many individuals within the mining communities depend for their survival. According to Amegbey and Adimado (2003), between 1989 and 2003 there were 11 officially reported cyanide spillages in Tarkwa and Obuasi, located in the Western and Ashanti Regions, respectively. Most of these occurred with catastrophic consequences (Akabzaa 2000). Elevated concentrations of heavy metals in various media such as soils, streams (including sediments), food crops (e.g. cassava and plantain), fish (e.g. mudfish), plants (e.g. water ferns and elephant grass) and humans have been reported (see Amegbey and Eshun 2003; Aryee et al. 2003; Donkor et al. 2006; Hilson 2006; Essumang et al. 2007; Tschakert and Singh 2007; Antwi-Agyei et al. 2009; Armah et al. 2012; Boateng et al. 2012; Bempah et al. 2013;).

3 The basic theoretical model

The theoretical model employed in the study is an extension of the work of Chang and Trivedi (2003). Their model formalizes self-medication, which is a risky investment, by assuming that a rational utility-maximizing agent balances the benefits and costs associated with self-medication. Like Chang and Trevedi (2003), we assume that a rational agent maximizes an expected utility function that depends on health status (h) and consumption of a composite good (x), subject to a budget constraint. Let the utility function be defined as:

$$u = u(x,h), \tag{1}$$

with $u_x > 0$, $u_h > 0$, $u_{xh} = u_{hx} > 0$ and $u_{xx}, u_{hh} < 0$. Chang and Trivedi (2003) assume that improvement in health status results from either professional care, which is relatively risk-free, or self-medication, which is risky.[4] In this study, we assume that health status depends on investment in health (M), which is a derived demand. Because of a number of exogenous environmental factors, the returns to such an investment are partly deterministic and partly stochastic. The stochastic component is assumed to have a one-sided distribution. Several factors could account for the uncertain health outcome, including misdiagnosis and reinfection resulting from repeated exposure to the emission of dangerous gases from the mines or leakage of heavy metals to water that is later used domestically. As noted earlier, enormous amounts of inorganic mercury and high concentrations of arsenic are present in areas close to gold mines (see e.g. Smedley 1996; Telmer and Veiga 2009). The health status can therefore be defined as:

[4] Note that professional care, which is considered safe, could be provided by a trained medical doctor or any individual trained to provide care, including trained traditional medical service providers. A study has found that, in 2008, Ghana had only 1,439 health care facilities for a population of more than 23.5 million people (Salisu and Prinz 2009). Moreover, more than one-half of patients in the country rely on traditional medicine and self-medication (van den Boom et al. 2004; Salisu and Prinz 2009), making non-orthodox medicine an integral part of healthcare in Ghana.

$$h = h_o + (r - \varepsilon)M \tag{2}$$

where h_0 is the initial or 'endowed' health status (long-term health), and $r-\varepsilon$ is the return to healthcare investment, r being the deterministic marginal return to the investment in health, and ε being the stochastic marginal return. Suppose the price of the composite good x is normalized to one. Then the agent's budget constraint is:

$$B = x + M \tag{3}$$

where B is the budget in real terms. The agent's corresponding expected utility function is:

$$Eu(x,h) = Eu\left(B - M, h_o + (r-\varepsilon)M\right) \tag{4}$$

Following Chang and Trivedi (2003), let the utility function be additive and separable

in x and h, so that:

$$u(x,h) = u(x) + v(h), \tag{5}$$

Also, let $v(h)$ be of the specific form:

$$v(h) = -{(\rho - h)^2}/{2}, \qquad \text{with } 0 \le h \le \rho \tag{6}$$

Using equations (5) and (6), we can rewrite equation (4) as:

$$Eu(x,h) = u(B - M) - E\left(\frac{\left(\rho - h_o - (r-\varepsilon)M\right)^2}{2}\right) \tag{7}$$

Let $\mu = E(r-\varepsilon)$ be the expected returns on healthcare investment and $\sigma^2 = E(r - \varepsilon - \mu)^2$

be the variance of $(r-\varepsilon)$. The mean-variance formulation of (7) is:

$$Eu(\bullet) = u(B - M) - \frac{\left(\rho - h_0 - \mu M\right)^2}{2} - \frac{\sigma^2 M^2}{2} \tag{8}$$

Maximizing equation (8) with respect to the choice variable (that is, M) yields the following first-order condition:

$$u_M(B - M) + (\rho - h_o - \mu M).\mu - \sigma^2 M = 0 \tag{9}$$

Equation (9) stipulates that, in equilibrium, the marginal health benefit from an increased investment in health—that is, $(\rho - h_o - \mu M).\mu - \sigma^2 M$ —must balance the marginal utility cost of the investment, which is $u_M(B-M)$. It can easily be shown that M decreases in h_o and σ^2, but increases in B and μ. Thus, $dM/dh_0 < 0$, $dM/d\mu > 0$, $dM/d\sigma^2 < 0$ and $dM/dB > 0$. The implications are that individuals with better long-term health status will make fewer investments in improving their health and, secondly, that high variance of the returns to health is likely to discourage healthcare spending. On the other hand, richer individuals will spend more on their healthcare, and higher returns on healthcare expenditure are likely to stimulate healthcare spending.

Finally, let the stochastic component of the health outcome depend on exposure to mining externalities, such as cyanide spillage, as well as a vector of individual characteristics ($\mathbf{A}$). The assumption follows Johansson's (1994) postulation that the impact of pollution on an individual's health status cannot be predicted with certainty. As a result, $\mu = \mu(\mathbf{z};\mathbf{A})$ and $\sigma = \sigma(\mathbf{z};\mathbf{A})$, where $\mathbf{z}$ is a vector of mining externalities (for example, nearness to the mining site, which is a proxy for exposure to pollution, or noise pollution from blasting, etc.). It is hypothesized that increased pollution decreases the expected returns to health expenditure, but the variance in pollution increases (i.e., $\mu_{\mathbf{z}} < 0$ and $\sigma^2_{\mathbf{z}} > 0$) so that $dM/dz < 0$. We can then specify the general form of healthcare investment equation as:

$$M = f(h_o, B, \mathbf{z}; \mathbf{A}) \tag{10}$$

Equation (10) is a *hedonic-type* equation, in which the economic cost of healthcare (both preventive and curative) depends on the level of environmental hazard to which an individual is exposed
($\mathbf{z}$), after controlling for other social, economic, and biophysical characteristics.[5]

4 Methodology

4.1 Primary data type and source

The data for the empirical analysis were collected through cluster sampling of 558 households in the Obuasi Municipality of the Ashanti Region of Ghana between May and July 2014. The municipality is approximately 162.4 square kilometres, and the Obuasi mine is the oldest gold mine still operating in the country. According to the most recent population census, the municipality is predominantly urban (GSS 2014b). Gold mining and its related activities constitute the municipality's main industrial activity and employs some 35 per cent of its working population. A questionnaire was administered to each selected household in a face-to-face interview. During the interview, each respondent was assured that his/her responses would remain strictly confidential. The questionnaire included questions on demographic characteristics

[5] A hedonic regression, which is a revealed preference method of estimating value, estimates the contributory value of each characteristic (i.e. explanatory variable) to the dependent variable (i.e. health spending). It does so by expressing the dependent variable as a function of its characteristics (i.e. explanatory variables). As a result, one is able to tell the extent to which distance to a major tailing impacts health expenditure.

(e.g. age and level of education), location of residence, and perceived typical health status of every household member. There were also questions on the general health condition of each household member (e.g. illnesses and injuries suffered, duration of illness and its effect on normal activities, and physician consultations during the previous 12 months). Each household member also indicated whether he/she had experienced any symptoms out of a list of symptoms of respiratory tract infections, diabetes, skin diseases, cardiovascular diseases and neurological disorders during a period of time. Out of these, the data listed in Table 1 were compiled.

4.2 Secondary data: nitrogen dioxide (NO_2) concentration

According to Aragón and Rud (2015), the main gas pollutant in the mining communities is nitrogen dioxide (NO_2). This is a yellow, brown, or orange coloured, acrid smelling gas. The authors, following Foster et al. (2009) and Jayachandran (2009), obtained satellite imagery from the Ozone Monitoring Instrument at NASA to investigate mining-related pollution within mining areas. The data on daily values of tropospheric air conditions includes NO_2, which originates mainly from combustion of hydrocarbons by large-scale mines.

Exposure to NO_2, which occurs through inhalation, may result in mild to catastrophic consequences. The Short Term Exposure Limit of the gas is 5 parts per million (ppm) (Queensland Department of Employment, Economic Development and Innovation 2011). While low concentration and duration of NO_2 can result in mild irritation of upper respiratory tract, prolonged inhalation could reach the air cell spaces of the lungs causing pain, shortness of breath, pneumonitis, and excess fluid in lung tissues (Queensland Department of Employment, Economic Development and Innovation 2011). Thus, the duration and concentration will determine the extent of damage to health.

We expected to find that the distance from the residences to the mining site correlates positively with households' exposure to pollution. Using their limited but highly correlated data points, we regressed NO_2 on distance and found an elasticity coefficient of -1.87, with an adjusted R-squared of 88 per cent (see Table B1). Thus, a 1 per cent increase in the distance to the mine decreases the concentration of the gas by approximately 1.9 per cent. The results were bootstrapped and found to be consistent even after 1,000 replications.

4.3 Empirical model

The specific functional form of hedonic models varies considerably in the literature. In reality, the specification that fits the data best depends on the issues under consideration and the data actually available. For example, in applying the model to pricing housing attributes, some studies have found that linear specifications best fit the data (see e.g. Rosen 1974; Cropper et al. 1988), while others have found non-linear relationships (see e.g. Halvorsen and Pollakowski 1981; Cassel and Mendelsohn, 1985; Colwell and Munneke 1999). Nonetheless, some studies advocate the use of nonparametric methods to avoid imposing a priori restrictions on the distribution of the error terms in such models (see e.g. Stock 1989; Meese and Wallace 1991; Thorsnes and McMillen 1998; Redfearn 2009). Taking a cue from the literature (and based on the data available), the following equation is proposed. It assumes that the relationship between healthcare cost and the quality of the environment can be linearized:

$$\ln(M_i) = f_i\left(h_o, B, \mathbf{z}, \mathbf{A}\right) + \omega_i = \alpha_0 + \alpha_1 h_{0_i} + \alpha_2 \ln\left(B_i\right) + \boldsymbol{\theta}'\mathbf{z}_i + \boldsymbol{\gamma}'\mathbf{A}_i + \omega_i \tag{11}$$

with $\alpha_1 < 0$, $\alpha_2 > 0$, and $\boldsymbol{\theta} < 0$ (based on equations A1–4 at Appendix A); where M_i is investment in health proxied by the per capita private healthcare expenditure of household i, and ω_i is a normally distributed error term (i.e., $\omega_i \sim N(0, \sigma_\omega^2)$. The private healthcare expenditure is calculated as household out-of-pocket expenditure on healthcare plus the opportunity cost of lost productivity and healthcare-related travel costs. The figure is then divided by the household size to arrive at M_i. As noted by Chang and Travedi (2003), the variable h_{0_i} is measured by the long-term health status of the individual. However, because of a lack of good data, they used variables reflecting current health status, for example, illness and injuries.

In this study, we proxy the variable by the respondent's subjective evaluation of the typical health conditions of household members, and current health conditions. The variable B_i is per capita household income, and the vector $\mathbf{A}_i$ includes the disease incidence of household members, and the age, gender, years of education, and marital status of the household head. For the variable $\mathbf{z}_i$, the shortest distance between the household and a major mine site was used as a proxy. Instrumental variable (IV) regression is estimated along with ordinary least squares (OLS).

5 Results

5.1 Descriptive statistics

The descriptive statistics of the data used for the empirical analysis are presented in Table 1. The average distance between the residences of the respondents and the mining sites was 1.4km, with a standard deviation of 1.7. (The relatively high standard deviation implies that some houses are much farther away from the mining sites than others.)

Nearly one-half (47 per cent) of the households interviewed had at least one case of lower respiratory tract infection, and on average the recurrence of skin diseases per household is 1.1. In other words, a skin infection recurred at least once in a household. The mean per capita household out-of-pocket healthcare expenditure, plus the opportunity cost of lost productivity and healthcare-related travel cost, was approximately GHS56, with a standard deviation of 49.[6] The per capita out-of-pocket healthcare expenditure in Ghana was GHS49.74 while the per capita total household expenditure was GHS3,117. The corresponding figure for urban areas, which was higher than for rural areas, was GHS3,926 (GSS 2014a). From the data we collected in Obuasi Municipality, which is predominantly urban area, the per capita household expenditure was about GHS3,900.

The respondents (i.e. household heads) were asked to evaluate their health status on a scale of 0 to 100 subjectively.[7] Studies have found that, when health information is lacking, individuals' subjective health assessment can be regarded as a legitimate indicator of overall health status (see e.g. Brook et al. 1979; Ferraro et al. 1997). The mean health status was found to be 80.5 per cent, which is quite high. Only 21 per cent of the households interviewed were headed by females, and the average age of the household head was 41 years, with a standard deviation of 11. Only one-

[6] At the time of the survey (May–July 2014) the exchange rate was US$1.00=GHS3.40.

[7] The choice of a scale of 0–100 is based on previous studies in similar communities in Ghana, which upon several pretests found that respondents were comfortable at expressing subjective evaluation of a number of variables on such a scale (see e.g. Akpalu 2008, 2011).

third of the household heads were unmarried, and their average number of years of education was 11 years, implying that most have at least a secondary school education. Finally, only 19 per cent of households had most of their hospital bills paid by a non-member of the household.

Table 1: Descriptive statistics of variables used in the analysis

Description	Mean	s.d	Min	Max
Distance from residence to major mine (pollutant) in km	1.448	1.705	0.02	10
Health expenditure per household member (GHS)	55.51	48.94	0	337.75
Per capita household health status per household member (%)	80.47	6.705	55	95
Household size (continuous)	3.14	1.77	1	10
Per capita household incidence of lower respiratory tract infections	0.47	0.399	0	1
Per capita household incidence of diabetes	0.109	0.245	0	1
Per capita household incidence of cardiovascular diseases	0.193	0.296	0	1
Per capita household incidence of neurological disorders	0.348	0.363	0	1
Skin infections recurrence per household	1.088	2.294	0	25
Age of household head	40.677	11.044	18	98
Gender of household head (male: 1, female: 0)	0.79	0.407	0	1
Years of education of household head	10.98	4.001	0	20
Per capita household expenditure (GHS)	3,876.41	1,999.44	98.9	16,269
Greater portion of hospital bills paid by non-household member	0.134	0.341	0	1
Marital status of household head (married: 1, unmarried: 0)	0.668	0.471	0	1
Per capita household work force	0.606	0.308	0	1
Take measures to stay healthy (yes: 1, no: 0)	0 343	0.475	0	1

Source: Authors' calculations based on field data.

5.2 Regression results

Two sets of regression equations are estimated: two-staged least squares compared with OLS regressions. Since it is possible that higher personal healthcare spending can improve one's health status while one's good long-term health status simultaneously reduces one's health expenditure, we suspect a bi-causal relationship between per capita household health status and per capita household health expenditure. We also suspect a bi-causal relationship between per capita household expenditure and per capita household health expenditure. As a result, we have estimated an instrumental variable (IV) regression or two-staged least squares (2SLS) regression. The following instruments are used: per capita incidence of lower respiratory tract infections, diabetes, cardiovascular diseases, and neurological disorders; the recurrence of skin infections; years of formal education; per capita household workforce, and a dummy variable for a collection of activities undertaken to prevent ill-health or maintain good health.

The results of the determinants of per capita household health expenditure within the mining community selected for the study are shown in Table B1 (Appendix B) and Table 2. Table B1 shows only the first stage of the instrumental variable (IV) estimation, while Table 2 shows both OLS and IV or 2SLS regression results. All the instruments are significant, an indication that they are correlated with the excluded or endogenous variables. The Shea's adjusted partial R-squared for per capita household health status and for per capita household expenditure are 0.175 and 0.191, respectively. The F-statistics reveal that the lines are a good fit at 1 per cent significance level ($P<0.00$)

Moreover, the IV results (Table 2) show improved coefficients compared to the OLS results. Additionally, the Sargan's score with a p-value of 0.42 indicates that the instruments are uncorrelated with the error term and that the IV equation is not mis-specified. This means the excluded variables need not be included in the structural equation. The minimum eigenvalue of 14.73 is greater than the 10 per cent critical value for the 2SLS relative bias of 10.22, implying that we cannot reject the null hypothesis that the instruments are weak. These conspire to indicate that the IV estimation is better than the OLS estimates.

The estimated coefficients of the following variables are statistically significant at 5 per cent level or better: distance from residence to the major mining site, per capita household health status, per capita household expenditure, age of household head, and the dummy variable representing whether or not the household itself pays most of its hospital bills.

Table 2: Regressions results of determinants of per capita household health expenditure in Ghana

Log of per capita household health expenditure	Coefficients		Elasticity
	OLS	IV	IV
Log (per capita household expenditure)	0.167	0.413	0.413
	(0.064)**	(0.178)**	
Per capita household health status (0–100%)	-.043	-0.128	-0.128
	(0.005)***	(0.014)***	
Log (distance between house and the nearest major mine)	-0.119	-0.118	-0.118
	(0.031)***	(0.042)***	
Male (1/0)	0.006	-0.167	-0.132
	(0.088)	(0.116)	
Household head is married (1/0)	-0.057	0.082	0.055
	(0.079)	(0.11)	
Age of household head	-0.005	-0.018	-0.737
	(0.003)*	(0.004)***	
Greater portion of hospital bills paid by non-household member (1/0)	-0.283	-0.246	-0.044
	(0.082)***	(0.107)**	
_cons	6.154	11.528	
	(0.690)***	(1.803)***	
N	545	545	
Adj R-squared	0.184		
Goodness of fit [Prob > F]	0.000		
Ramsey RESET test F(3, 534) = 0.72 Prob > F	0.543		
Breusch-Pagan/Cook-Weisberg test for het.	0.416		
First stage:			
Shea's Adj Partial R-sq			
Health status		0.175	
Total household expenditure		0.191	
Minimum eigenvalue statistic		14.73	
10% critical values for 2SLS relative bias		10.22	
# of endogenous regressors			
# of excluded instruments		2	
		8	
Sargan's (score) Chi^2(6) = 5.99		p = 0.424	
Basmann Chi^2(6) = 5.901		P = 0.434	

Note: Standard errors in parentheses. * significance at 10%; ** significance at 5%; *** significance at 1%.

Source: Authors' calculations based on field data.

The coefficient of perceived health status is negative and statistically significant at 1 per cent level. Thus, as predicted by our theoretical construct, individuals with better general health status, all else being equal, spend less on healthcare. This is consistent with the finding that healthcare in Africa is primarily curative (Murthy and Okunade 2009). The corresponding elasticity coefficient is -0.03 (inelastic), which indicates that healthcare expenditure is marginally sensitive to perceived health status.

Also confirmed is our hypothesis that higher income-earning households, all things being equal, spend more on healthcare. The positive relationship between healthcare spending and real income has also been found for an African-wide study (Murthy and Okunade 2009). The coefficient is significant at 5 per cent level, with an elasticity coefficient of 0.41, suggesting that healthcare is a normal good.

The data also support our critical hypothesis that distance to the nearest major mining site, a proxy for exposure to pollution, is positively related to healthcare expenditure. The coefficient of the variable is statistically significant at 1 per cent level and the corresponding elasticity coefficient is -0.12. This implies that healthcare expenditure may increase by 0.12 per cent as a result of a 1 per cent decrease in the average distance from the residence to the mining site. Conversely, the marginal WTA compensation for healthcare expenditure (curative and preventive) as a result of exposure to pollution from the mining activities, all else being equal, is higher for households that are closer to the mining sites. Existing biochemical studies in Ghana have found significant health impacts of heavy metals such as arsenic, mercury, cadmium, and lead (Essumang 2009; Voegborlo et al. 2010; Armah et al. 2012).

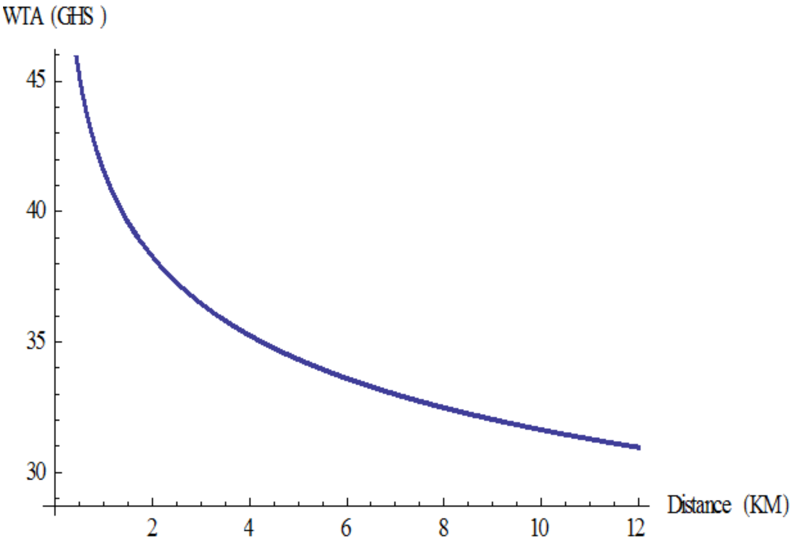
Furthermore, households with relatively older heads spend less on healthcare compared to those headed by younger individuals. This may be indicative of the income or earnings of the household heads. Older household heads, all else being equal, may have less income and assets and, for that reason, have less money to spend on healthcare. Surprisingly, the variable had the highest elasticity coefficient, -0.74. This contrasts with a cross country study on Africa, which found that national healthcare expenditure is not significantly impacted by the proportion of the older population within a country (Murthy and Okunade 2009). Also, as argued by Zhang and Imai (2007), it is the ageing process and the likelihood of death as one ages that leads to increased healthcare spending not the age of an individual. Thus, the direction of the relationship between the age of an individual and his/her healthcare spending is an empirical one.

Finally, because of the difficulties associated with recall, the respondents were not asked to provide the exact healthcare expenditure of their employer or health insurance plan. Rather, the respondent was asked to indicate whether someone other than a direct household member paid a bigger share of the household member's healthcare expenses. The regression results show that, on average, a respondent whose employer or health insurance plan paid a greater portion of his/her hospital bill had lower personal healthcare expenditure than his/her counterparts who carried a bigger burden of their own healthcare costs. The corresponding elasticity coefficient is 0.04, which is quite low (that is, highly inelastic).

5.3 The WTA compensation for mining pollution

As noted earlier, the minimum compensation in healthcare expenditure regarded as acceptable to victims of mining pollution within the municipality decreases with the distance from the person's residence to the major mining site. Using Equation 11, the negative relationship between the two variables, if all other explanatory variables are evaluated at their mean values, can be illustrated by Figure 2. Households closest to a major mining site (0.02km) were willing to accept a minimum of GHS68.79 per annum per household member, while those farthest from the mine (10.0km) required an average compensation of only GHS33.27 per annum per household member.

Figure 2: WTA compensation: the proximity–health expenditure trade-off



Source: Drawing based on Authors' analysis of field data.

The WTA compensation is obtained by multiplying the frequencies of the residence-to-mining-site distances by the WTA and summing up the outcomes. The computed value for the total respondents is about GHS23,348.14 per annum. The corresponding mean WTA is GHS41.20, which is lower than the national average per capita out-of pocket healthcare expenditure (i.e. GHS49.74).

5.4 WTP and NO_2 concentration

According to the World Health Organization (WHO), a strong correlation generally exists between concentrations of NO_2 and other toxic pollutants (WHO 2006). As a result, NO_2 is often used as a proxy or surrogate for the presence of pollutants as a whole, since it is often easier to measure. Following this assertion, it is straightforward to estimate WTA compensation elasticity with respect to the pollution concentration, which is the product of WTA compensation elasticity with respect to distance and distance elasticity with respect to NO_2.[8] Using the corresponding figures from Table B2 (i.e.-1.87^{-1}) and Table 4 (i.e. -0.118), the elasticity coefficient is 0.06. Thus, a 10 per cent increase in NO_2 concentration will increase the WTA compensation by 0.6 per cent.

6 Concluding remarks

In many mineral-rich African countries, including Ghana, lax environmental policies, combined with perceived opportunities for financial gain, have resulted in the discharge of large quantities of toxic chemicals such as mercury, cyanide, and arsenic and their harmful compounds into the natural environment, exposing workers and residents to a range of health conditions, from lower respiratory tract infections to cardiovascular and skin diseases. To the best of our knowledge, no study has been undertaken to directly evaluate the effect of exposure to mining pollution on

[8] Note that if $y = f\left(x(v)\right)$, then the elasticity of y with respect to v is $\eta_{yz} = \left(\frac{f_x . x}{f}\right) \bullet \left(\frac{x_v . v}{x}\right)$.

healthcare expenditure among residents of mining communities. A simple hedonic-type model employed in this study confirms that exposure to gold mining pollution has an impact on private healthcare expenditure, after controlling for a number of variables including current and long-term health status, and household income.

Perhaps quite intriguing is the finding that older residents spend less on their health, compared to their younger counterparts. This may appear surprising, since older individuals are expected to have greater health needs. However, the findings from the literature indicate that pure age effect on healthcare spending cannot be determined a priori. Based on our results, public policy may be required to support older people, if it is clearly established that income poverty is the driving force of the low spending.

Furthermore, the finding that wealthier households spend more on healthcare than their poorer counterparts suggests that public policies that create jobs and improve incomes of the residents within the mining communities are likely to promote good health. As noted earlier, mining communities in Ghana are bedevilled with high poverty rates.

Finally, by directly linking mining pollution concentration to healthcare spending and the monetary measure of the local benefits of regulation, public policy on compensation could be better estimated and better targeted.

This study, though intriguing, is not without shortcomings, primarily related to data. The reliance on subjective assessment of health status of the respondents, although employed by other studies, could suffer from human errors. In addition, as indicated, data from an earlier biophysical study was employed to draw the link between distance to tailings and pollution concentration within the mining communities. Future extensions of this work should consider these limitations and employ physical and biochemical data to enrich the analysis.

References

Adei, D, I. Addei, and H.A. Kwadjosse (2011). 'Study of the Effects of Mining Activities on the Health Status of People: A Case Study'. *Research Journal of Applied Sciences, Engineering and Technology*, 3(2): 99–104.

Akabzaa, T.M. (2000). *Boom and Dislocation: The Environmental and Social Impacts of Mining in the Wassa West District of Ghana*. Accra, Ghana: Third World Network Africa.

Akabzaa, T.M. (2009). 'Mining in Ghana: Implications for National Economic Development and Poverty Reduction'. In B. Campbell (ed.), *Mining in Africa Regulation and Development*. New York: Pluto Press.

Akabzaa, T.M., B.K. Banoeng-Yakubo, and J.S. Seyire (2007). 'Impact of Mining Activities on Water in the Vicinity of the Obuasi Mine'. *West African Journal of Applied Ecology,* 11. Available at: http://www.ajol.info/index.php/wajae/article/view/45719 (accessed on 17 October 2016)

Akabzaa, T.M. and, A. Darimani (2001). 'Impact of Mining Sector Investment in Ghana: A Study of the Tarkwa Mining Region'. Draft report prepared for SAPRI. Available at: http://siteresources.worldbank.org/INTOGMC/Resources/336099-1163605893612/hintonrolereview.pdf (accessed on 29 July 2015).

Akpalu, W. (2008). 'Fishing Regulations, Individual Discount Rate, and Fisherman Behavior in a Developing Country Fishery'. *Environment and Development Economics*, 13(05): 591–606.

Akpalu, W. (2011). 'Determinants of Noncompliance with Light Attraction Regulation among Inshore Fishers in Ghana'. *The Journal of Socio-Economics*, 40(2): 172–77.

Amegbey, N.A., and A.A. Adimado (2003). 'Incidents of Cyanide Spillage in Ghana'. *Mineral Processing and Extractive Metallurgy*, 112(2): 126–130.

Amegbey N.A., and P.A. Eshun (2003). 'Mercury Use and Occupational Exposure in the Ghanaian Small-scale Gold Mining Industry'. *Ghana Mining Journal*, 7: 54–61.

Antwi-Agyei P., J.N. Hogarh, and G. Foli (2009). 'Trace Elements Contamination of Soils around Gold Mine Tailings Dams at Obuasi, Ghana'. *African Journal of Environmental Science and Technology*, 3(11): 353–59.

Anyemedu, K. (1992). 'Planning for a Wider Impact of the Mining Industry on the Community'. In K. Aryeetey (ed.), *Planning African Growth and Development: Some Current Issues*. Accra: ISSER/UNDP.

Aragón, F.M., and J.P. Rud (2015). 'Polluting Industries and Agricultural Productivity: Evidence from Mining in Ghana'. *The Economic Journal*, (accepted manuscript).

Armah F.A., I. Luginaah, and S. Obiri (2012). 'Assessing Environmental Exposure and Health Impacts of Gold Mining in Ghana'. *Toxicological & Environmental Chemistry*, 94(4): 786–98.

Armah, F.A., S. Obiri, D.O. Yawson, A.N.M. Pappoe, and B. Akoto. (2010). 'Mining and Heavy Metal Pollution: Assessment of Aquatic Environments in Tarkwa (Ghana) Using Multivariate Statistical Analysis'. *Journal of Environmental Statistics*, 14: 1–13.

Aryee B.N.A., B.K. Ntibery, and E. Atorki (2003). 'Trends in the Small-scale Mining of Precious Minerals in Ghana: A Perspective on its Environmental Impact'. *Journal of Cleaner Production*, 11: 131–140.

Bempah C.K., A. Ewusi, S. Obiri-Yeboah, S.B. Asabere, F. Mensah, J. Boateng, and H.-J. Voigt (2013). 'Distribution of Arsenic and Heavy Metals from Mine Tailings Dams at Obuasi Municipality of Ghana'. *American Journal of Engineering Research (AJER)*, 2(5): 61–70.

Boateng E., G.N.N. Dowuona, P.M. Nude, G. Foli, P. Gyekye, and H.M. Jafaru (2012). 'Geochemical Assessment of the Impact of Mine Tailings Reclamation on the Quality of Soils at AngloGold Concession, Obuasi, Ghana'. *Research Journal of Environmental and Earth Sciences*, 4(4): 466–74.

Britwum, A., K. Johan, and F. D. Tay (2001). 'Structural Adjustment Participatory Review Initiative (SAPRI)'. Ghana Country Report. Washington, DC: Tripartite National Steering Committee, Structural Adjustment Participatory Review Initiative Network (SAPRIN). Available at: http://www.saprin.org/ghana/research/ gha_country_rpt.pdf (accessed on 5 December 2014).

Brook, R.H., J.E. Ware, A. Davies-Avery, A.L. Stewart, C.A. Donald, and W.H. Rogers (1979). 'Overview of Adult Health Status Measures Fielded in RAND's Health Insurance Study'. *Medical Care*, 17(7 Suppl.): iii-x, 1–131.

Cassel, E., and R. Mendelsohn (1985). 'The Choice of Functional Forms for Hedonic Price Equations: Comment'. *Journal of Urban Economics*, 18: 135–42.

Chang F.-R. and P. K. Trivedi (2003). 'Economics of self-medication: Theory and evidence', *Health Economics*, 12:721-739.

Colwell, P.F., and H.J. Munneke (1999). 'Land Prices and Land Assembly in the CBD'. *The Journal of Real Estate Finance and Economics*, 18(2): 163–180.

Cropper M.L., L.B. Deck, and K.E. McConnell. (1988). 'On the Choice of Functional Form for Hedonic Price Functions'. *The Review of Economics and Statistics,* 70(4): 668–75.

Currie, J., J.S.G. Zivin, J. Mullins, and M.J. Neidell (2014). 'What Do we Know about Short- and Long-term Effects of Early-life Exposure to Pollution?'. *Annual Review of Resource Economics*, 6: 217–47.

Donkor A.K., J.C. Bonzongo, V.K. Nartey, and D.K. Adotey (2006). 'Mercury in Different Environmental Compartments of the Pra River Basin'. *Ghana. Science of the Total Environment*, 386: 164–76.

Essumang, D.K. (2009). 'Levels of Arsenic in Human Hair as Biomarkers of Arsenic Exposure in a Mining Community in Ghana'. *Bulletin of the Chemical Society of Ethiopia,* 23: 275–80.

Essumang D.K., D.K. Dodoo, S. Obiri, and J.Y. Yaney (2007). 'Arsenic, Cadmium, and Mercury in Cocoyam (Xanthosoma Sagititolium) and Watercocoyam (Colocasia Esculenta) in Tarkwa a Mining Community'. *Bulletin of Environmental Contamination and Toxicology,* 79(4): 377-79.

Ferraro, K.F., M.M. Farmer, and J.A. Wybraniec (1997). 'Health Trajectories: Long-term Dynamics among Black and White Adults'. *Journal of Health and Social Behavior,* 38: 38–54.

Ferring, D., H. Hausermann, and E. Effah (2016). 'Site Specific: Heterogeneity of Small-scale Gold Mining in Ghana'. *The Extractive Industries and Society*, 3(1): 171–84.

Foster, A., E. Gutierrez, and N. Kumar (2009). 'Voluntary Compliance, Pollution Levels, and Infant Mortality in Mexico'. *American Economic Review*, 99(2): 191–7.

Ghana Chamber of Mines (2008). 'Factoid 2008'. Available at: http://ghanachamberofmines.org/en/our-publications.php (accessed on 17 October 2016).

Ghana Chamber of Mines (2011). 'Factoid 2011'. Available at: http://ghanachamberofmines.org/en/our-publications.php (accessed on 17 October 2016).

Ghana Chamber of Mines (2013). 'Performance_of_the_Mining_Industry_in_2013'. Available at: http://ghanachamberofmines.org/media/publications/Performance_of_the_Mining_Industry_in_2013.pdf (accessed on 17 October 2016).

Gough, K.V., and P.W. Yankson (2012). 'Exploring the Connections: Mining and Urbanisation in Ghana'. *Journal of Contemporary African Studies*, 30(4): 651–68.

Graff Zivin, J.S., and M.J. Neidell (2013). 'Environment, Health, and Human Capital'. *Journal of Economic Literature*, 51(3): 689–730.

GSS (Ghana Statistical Service) (2014a). *Ghana Living Standards Survey Round 6 (GLSS6). Main Report.* Accra: Ghana Statistical Services.

GSS (Ghana Statistical Service) (2014b). *2010 Population and Housing Census: District Analytical Report. Obuasi Municipality*. Accra: Ghana Statistical Services.

Halvorsen, R., and H.O. Pollakowski (1981). 'Choice of Functional Form for Hedonic Price Equations'. *Journal of Urban Economics*, 10(1): 37–49.

Hilson, G. (2006). 'Abatement of Mercury Pollution in the Small-scale Gold Mining Industry: Restructuring the Policy and Research Agendas'. *Science of the Total Environment*, 362: 1–14.

Hilson, G.M. and C.J. Garforth (2012). '"Agricultural Poverty" and the Expansion of Artisanal Mining in Sub-Saharan Africa: Experiences from Southwest Mali and Southeast Ghana'. *Population Research and Policy Review*, 31: 435–64.

Hilson G., and F. Nyame (2006). ‘Gold Mining in Ghana’s Forest Reserves: A Report on the Current Debate’. *Area*, 38(2): 175–85.

ILO (2005). ‘Global Estimates of Fatal Work Related Diseases and Occupational Accidents, World Bank Regions 2005’. Available at: http://www.ilo.org/legacy/english/protection/safework/accidis/globest_2005/index.htm (accessed on 12 August 2014).

Jayachandran, S. (2009). ‘Air Quality and Early-life Mortality: Evidence from Indonesia’s Wildfires’. *Journal of Human Resources*, 44(4): 916–54.

Johansson, P.O. (1994). ‘Valuing Changes in Health: A Production Function Approach’. In R. Pethig (ed.), *Valuing the Environment: Methodological and Measurement Issues*. Dordrecht, the Netherlands: Kluwer Academic Publishers.

Meese, R., and N. Wallace (1991). ‘Nonparametric Estimation of Dynamic Hedonic Price Models and the Construction of Residential Housing Price Indices’. *Real Estate Economics, American Real Estate and Urban Economics Association*, 19(3): 308–32.

McMahon, G. (2011). ‘What are the Impacts of the African Mining Sector Liberalization?’. *PROPARCO Magazine*, 8: 12–16.

Mergler, D., H.A. Anderson, L.H.M. Chan, K.R. Mahaffey, M. Murray, M. Sakamoto, and A.H. Stern (2007). ‘Methylmercury Exposure and Health Effects in Humans: A Worldwide Concern’. *Ambio,* 36(1).

Murthy, V.N., and A.A. Okunade (2009). ‘The Core Determinants of Health Expenditure in the African Context: Some Econometric Evidence for Policy’. *Health Policy*, 91(1): 57–62.

Naicker, K., E. Cukrowska, and T.S. McCarthy (2003). ‘Acid Mine Drainage Arising from Gold Mining Activity in Johannesburg, South Africa and Environs’. *Environmental Pollution*, 122(1): 29–40.

Redfearn, C.L. (2009). ‘How Informative are Average Effects? Hedonic Regression and Amenity Capitalization in Complex Urban Housing Markets’. *Regional Science and Urban Economics*, 39: 297–306.

Rosen, S. (1974). ‘Hedonic Prices and Implicit Markets: Product Differentiation in Pure Competition’. *Journal of Political Economy,* 82(1): 35–55.

Saldarriaga-Isaza, A., C. Villegas-Palacio, and S. Arango (2013). ‘The Public Good Dilemma of a Non-renewable Common Resource: A Look at the Facts of Artisanal Gold Mining’. *Resources Policy*, 38(2): 224–32.

Salisu, A., and V. Prinz (2009). *Healthcare in Ghana*. Vienna: Austrian Centre for Country of Origin & Asylum Research and Documentation, ACCORD and Austrian Red Cross.

Smedley P.L. (1996). ‘Arsenic in Rural Groundwater in Ghana’. *Journal of African Earth Sciences*, *22* (4): 459–70.

State of Queensland Department of Employment, Economic Development and Innovation (2011). ‘Management of Oxides of Nitrogen in Open Cut Blasting’. Queensland Guidance Note QGN 20. Available at: https://www.dnrm.qld.gov.au/__data/assets/pdf_file/0010/212500/qld-guidance-note-20-mgmt-oxides-nitrogen.pdf (accessed on 17 October 2016).

Stock, J.H. (1989). ‘Nonparametric Policy Analysis’. *Journal of the American Statistical Association*, 84: 567–75.

Telmer, K.H., and M.M. Veiga (2009). 'World Emissions of Mercury from Artisanal and Small Scale Gold Mining'. In N. Pirrone and R. Mason (eds), *Mercury Fate and Transport in the Global Atmosphere: Emissions, Measurements and Models*. New York, NY: Springer.

Thorsnes, P., and D.P. McMillen (1998). 'Land Value and Parcel Size: A Semiparametric Analysis'. *The Journal of Real Estate Finance and Economics,* 17(3): 233–44.

Tschakert, P., and K. Singh (2007). 'Contaminated Identities: Mercury and Marginalization in Ghana's Artisanal Mining Sector'. *Geoforum*, 38: 1304–21.

van den Boom, G.J.M, N.N.N. Nsowah-Nuamah, and G.B. Overbosch. (2004). *Healthcare Provision and Self-medication in Ghana*. Amsterdam: Centre for World Food Studies.

Voegborlo, R.B., A. Matsuyama, A.A. Adimado, and H. Akagi. (2010). 'Head Hair Total Mercury and Methylmercury Levels in some Ghanaian Individuals for the Estimation of their Exposure to Mercury: Preliminary Studies'. *Bulletin of Environmental Contamination and Toxicology*, 84: 34–38.

WHO (2006). *Air Quality Guidelines for Particulate Matter, Ozone Nitrogen Dioxide and Sulphur Dioxide: Global Update 2005: Summary of Risk Assessment*. Geneva: World Health Organization.

Yidana, S.M., D. Duke Ophori, and B. Banoeng-Yakubo (2007). 'A Multivariate Statistical Analysis of Surface Water Chemistry Data—the Ankobra Basin, Ghana'. *Journal of Environmental Management,* 86: 80–87.

Zhang, P., and K. Imai (2007). 'The Relationship between Age and Healthcare Expenditure among Persons with Diabetes Mellitus'. *Expert Opinion on Pharmacotherapy,* 8(1): 49–57.

Appendix A

$$dM/dh_0 = \frac{\mu}{\left(u_{MM}(\bullet) - \mu^2 - \sigma^2\right)} < 0 \tag{A1}$$

$$dM/d\mu = \frac{-\left(\rho - h_o - 2\mu M\right)}{\left(u_{MM}(\bullet) - \mu^2 - \sigma^2\right)} > 0 \tag{A2}$$

$$dM/d\sigma^2 = \frac{M}{\left(u_{MM}(\bullet) - \mu^2 - \sigma^2\right)} < 0 \tag{A3}$$

$$dM/dB = \frac{u_{MB}(\bullet)}{\left(u_{MM}(\bullet) - \mu^2 - \sigma^2\right)} > 0 \tag{A4}$$

Appendix B

Table B1: First-stage results of Instrumental Variable Regression

	Coefficients	
	Per capita household health status%	Log (per capita household expenditure)
Log (distance between house and the nearest major mine pollutant)	-0.418 (0.255)	-0.053 (0.019)***
Male (1,0)	-1.905 (0.747)**	0.026 (0.055)
Household head is married (1,0)	0.555 (0.669)	-0.154 (0.049)***
Age of household head	-0.151 (0.024)***	-0.003 (0.002)
Greater portion of hospital bills paid by non-household member (1,0)	0.688 (0.683)	0.149 (.05)***
Per capita household incidence of lower respiratory tract infections (LRTI)†	-1.434 (0.84)*	0.057 (0.061)
Per capita household incidence of diabetes †	-1.704 (0.908)*	0.105 (0.066)
Per capita household incidence of cardiovascular diseases†	-3.972 (1.046)***	-0.009 (0.076)
Per capita household incidence of neurological disorders†	-1.693 (0.915)*	-0.06 (0.067)
Skin infections recurrence per household†	-0.304 (0.114)***	-0.024 (0.008)***
Per capita household labour force†	1.244 (0.938)	0.624 (0.069)***
Cardiovascular exercise†	-1.813 (0.564)***	0.087 (0.041)**
Years of education of household head†	0.147 (0.069)**	0.014 (0.005)***
_cons	88.58 (1.482)***	7.739 (0.108)***
N	545	545
Adjusted R-squared	0.175	0.191
F(13, 531) = 14.51 Prob > F	0.000	
F(13, 531) = 18.84 Prob > F		0.000

Note: Standard errors in parentheses. * significance at 10%; ** significance at 5%; *** significance at 1%.
† Instrumental variable.

Source: Authors' calculations based on field data.

Table B2: Regression results of bootstrap data of effect of distance (km) on nitrogen dioxide (NO_2) concentration

Number of replications	100	500	1,000
Distance (Km)	-0.022 0.006)***	-0.022 (0.007)***	-0.022 (0.007)***
_cons	0.825 (0.139)***	0.825 (0.209)***	0.825 (0.202)***
Elasticity	-1.87	-1.87	-1.87
Number of Observations (4)			
Wald chi2(1)	13.85	9.10	9.63
Prob> chi2	0.000	0.003	0.002
Adj R-squared	0.876	0.876	0.876

Note: Bootstrapped standard error in parentheses; * significant at 10%, ** significant at 5%, *** significant at 1%.

Source: Authors' calculations based on data from Aragón and Rud (2015).