



## Analysis

Gold Mining Pollution and the Cost of Private Healthcare: The Case of Ghana<sup>☆</sup>Wisdom Akpalu<sup>a,\*</sup>, Ametefee K. Normanyo<sup>b</sup><sup>a</sup> United Nations University's World Institute for Development Economics Research (UNU-WIDER), C/O University of Ghana, Legon-Accra, Ghana<sup>b</sup> Ho Technical University (HTU), P. O. Box HP217, Ho, 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 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. This has been confirmed by our empirical results, with an elasticity coefficient of 0.12. Furthermore, while healthcare expenditure does not vary between males and females, younger household heads spend more on their health than their older counterparts after controlling for health status, income and access to health insurance.

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## 1. Introduction

Studies have shown that gold extraction and processing can significantly degrade natural environments (including soil and sediments, water, and air quality) and, with that, human health and livelihoods (Hilson, 2000; Akpalu and Parks, 2007; Obiri, 2007; Leder et al., 2012; Saldarriaga-Isaza et al., 2013; Ako et al., 2014; Ansa-Asare et al., 2015). The pollution mainly occurs during gold extraction and processing, which includes carbon-in-leach, heap leaching with cyanide, biological oxidation and roasting (Hilson, 2002; Leder et al., 2012). However, the existing laws in developing countries fail to effectively regulate the gold mining industries leading to excessive environmental degradation (Hilson, 2000).

Thus, in gold-rich countries in Africa, gold miners, both large- and small-scale, routinely discharge toxic chemicals such as mercury (typically used by small scale miners), 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 diseases (Franchini and Mannucci, 2007, 2009, and Franchini and Mannucci, 2012; Mergler et al., 2007; Banchirigah, 2008; Obiri et al., 2010), skin infections, and cancerous infections (Amegbey and

Adimado, 2003; Adei et al., 2011; Obiri et al., 2010).<sup>1</sup> A recent review of arsenic concentration in surface and underground water, for example, found mining as a major cause of high concentration of the hazardous substance in several African countries (Ahoulé et al., 2015). Some of the environmental and human damage can be irreversible (see e.g., Naicker et al., 2003; Stephens and Ahern, 2001).

In Ghana, for example, several studies have documented heaped waste materials at mining sites, which have resulted in the release of toxic chemicals into the environment (see e.g., Akabzaa et al., 2005; Essumang et al., 2007; Yidana et al., 2007; and Armah et al., 2010). The Council on Ethics of the Norwegian 'Government Pension Fund Global' carried out a detailed survey on mining pollution at the oldest gold mining town (Obuasi) and found evidence of severe environmental and health damage due to high level of concentration of arsenic, cyanide and heavy metals (e.g. cadmium, manganese, lead and copper) in water bodies (Leder et al., 2012). An earlier study also cited eight cases of cyanide spillage within a decade and a half (Amegbey and Adimado, 2003), which prompted the Ghana's Environmental Protection Agency (EPA) to remark that the nation is likely to experience water stress in less than a decade (Banchirigah, 2008).

In addition to water pollution, the use of heavy machinery in extracting the ore, coupled with the surface mining techniques

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<sup>1</sup> 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., 2005; Essumang et al., 2007; Yidana et al., 2007; and Armah et al., 2010; Amegbey and Adimado, 2003)

commonly employed by miners in developing countries, generates substantial dust which can cause or exacerbate respiratory disorders (Ayine, 2001; ILO, 2005; Kumah, 2006). Yet, such damages are rarely internalized 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). In Ghana, although mining companies have generally improved their environmental reporting in recent times, the ecosystem and health damage persist over the long-term (Leder et al., 2012). Moreover, the pollution generated by small scale miners continues to escalate (Leder et al., 2012).

Although a number of studies have been undertaken on the health impact of gold extraction (see, e.g., Graff Zivin and Neidell, 2013; and Currie et al., 2014), 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 the closer the household is to a tailing site or the mine.

Furthermore, using anecdotal evidence about the relationship between distance to the tailing site and concentration of nitrogen dioxide ( $\text{NO}_2$ ), 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 mining pollution. 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.

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-fourth of capital investment against taxes in the first year and one-half for subsequent years, a reduction in royalty rate from 6 to 3%, and the scrapping of all other duties and taxes (Akabzaa and Darimani, 2001; Aryee, 2014). 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 could retain between 25 and 45% 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 eleven 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., 31,103 kg), significantly up from 327,000 in 1987 (see Fig. 1).<sup>2</sup>

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 total approximately US\$6.9 billion between 2000 and 2011.

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; generate limited job opportunities, especially for the individuals in mining communities; took away farmlands and 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).

Throughout Ghana, there is sufficient evidence of serious environmental and health damages due to gold mining activities (Ahmad and Carboo, 2000; Hilson and Nyame, 2006; Leder et al., 2012; Mensah et al., 2015). 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 (Bempah et al., 2013; Boateng et al., 2012; Antwi-Agyei et al., 2009; Armah et al., 2012). 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, 2004; 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 Bempah et al., 2013; Boateng et al., 2012; Antwi-Agyei et al., 2009; Amegbey and Eshun, 2003; Aryee et al., 2003; Hilson, 2006; Tschakert and Singh, 2007; Donkor et al., 2006; Essumang et al., 2007; Armah et al., 2012).

## 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 Trivedi (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:

$$u = u(x, h), \quad (1)$$

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.<sup>3</sup> In this study, we assume that health status depends on

<sup>3</sup> Note that a 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 1439 health care facilities for a population of >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.

<sup>2</sup> A fine ounce (troy ounce) is equivalent to 31.1034768 g.

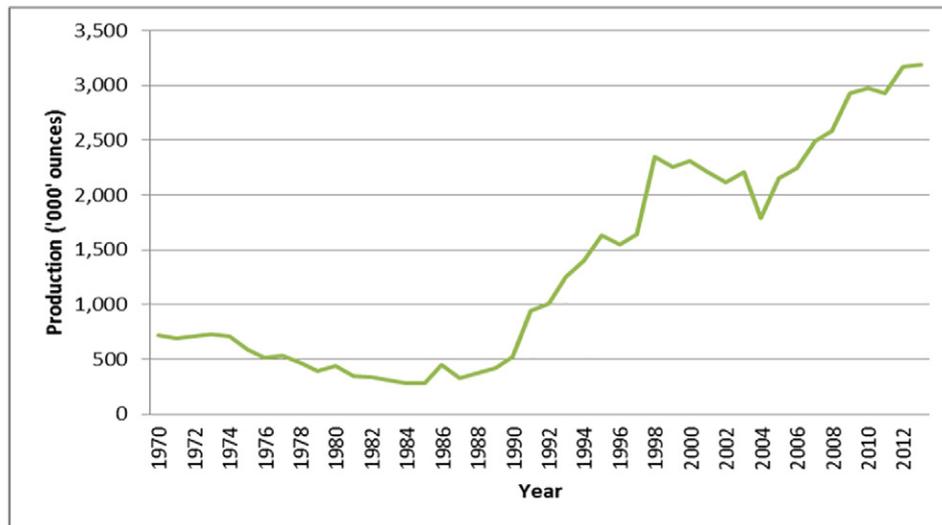


Fig. 1. Trends in gold production in Ghana 1970–2013 ('000' ounces).

Source: <sup>1</sup>1970–1999 Minerals Commission, Statistical overview of Ghana's mining industry; <sup>2</sup>2000–2013 Ghana Chamber of Mines Annual Reports.

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; and Telmer and Veiga, 2009). The health status can therefore be defined as:

$$h = h_0 + (r - \varepsilon)M \quad (2)$$

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  $\varepsilon$  being the stochastic marginal return. Suppose the price of the composite good  $x$  is normalized to one. Then the agent's budget constraint is:

$$B = x + M \quad (3)$$

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

$$Eu(x, h) = Eu(B - M, h_0 + (r - \varepsilon)M) \quad (4)$$

Following Chang and Trivedi (2003), let the utility function be additive and separable in  $x$  and  $h$ , so that:

$$u(x, h) = u(x) + v(h), \quad (5)$$

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

$$v(h) = -(\rho - h)^2 / 2, \quad \text{with } 0 \leq h \leq \rho \quad (6)$$

Using Eqs. (5) and (6), we can rewrite Eq. (4) as:

$$Eu(x, h) = u(B - M) - E\left(\frac{(\rho - h_0 - (r - \varepsilon)M)^2}{2}\right) \quad (7)$$

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 Eq. (7) is:

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

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

$$u_M(B - M) + (\rho - h_0 - \mu M) \cdot \mu - \sigma^2 M = 0 \quad (9)$$

Eq. (9) stipulates that, in equilibrium, the marginal health benefit from an increased investment in health—that is,  $(\rho - h_0 - \mu M) \cdot \mu - \sigma^2 M$ —must balance the marginal utility cost of the investment, which is  $u_M(B - M)$ . It can easily be shown that  $M$  decreases in  $h_0$  and  $\sigma^2$ , but increases in  $B$  and  $\mu$ . Thus,  $\frac{dM}{dh_0} < 0$ ,  $\frac{dM}{d\mu} > 0$ ,  $\frac{dM}{d\sigma^2} < 0$  and  $\frac{dM}{dB} > 0$ . 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  $\sigma_{\mathbf{z}}^2 > 0$ ) so that  $\frac{dM}{d\mathbf{z}} < 0$ . We can then specify the general form of healthcare investment equation as:

$$M = f(h_0, B, \mathbf{z}; \mathbf{A}) \quad (10)$$

Eq. (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.<sup>4</sup>

## 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 km<sup>2</sup>, and the Obuasi mine is the oldest gold mine in the country. It began operation in 1897 but the mining activities were suspended in late 2014 due to heavy losses recorded. Due to high levels of mining pollution in the mining area, compared to all other mining areas in the country, the mining company (AngloGold Ashanti) estimated the rehabilitation costs upon closure to be the highest. According to the most recent population census, the municipality is predominantly urban (GSS, 2014a). Gold mining and its related activities constitute the municipality's main industrial activity and employs some 35% of its working population. A questionnaire was administered to each randomly selected household in a face-to-face interview. Thus, each relevant question on the questionnaire was read out in English language and/or the local language to the respondent and his/her response was recorded. During the interview, each respondent was assured that his/her responses would remain strictly confidential. The questionnaire included questions on demographic characteristics (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. Out of these, the data listed in Table 1 were compiled.

### 4.2. Secondary Data: Nitrogen Dioxide (NO<sub>2</sub>) Concentration

According to Aragón and Rud (2015), the main gas pollutant in the mining communities is nitrogen dioxide (NO<sub>2</sub>). 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 (OMI) at NASA to investigate mining related pollution within mining areas. The data on daily values of tropospheric air conditions includes NO<sub>2</sub>, which originates mainly from combustion of hydrocarbons by large-scale mines.

Exposure to NO<sub>2</sub>, which occurs through inhalation, may result in mild to catastrophic consequences. 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<sub>2</sub> 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<sub>2</sub> on distance and found an elasticity coefficient of  $-1.87$ , with an

<sup>4</sup> 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 impact health expenditure.

**Table 1**  
Descriptive statistics of variables used in the analysis.  
Source: Field data.

| 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)                               | 3876.41 | 1999.44 | 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      |

adjusted R-squared of 88% (see Table B1). Thus, a 1% increase in the distance to the mine decreases the concentration of the gas by approximately 1.9%. The results were bootstrapped and found to be consistent even after 1000 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:

$$\ln(M_i) = f_i(h_0, B, \mathbf{z}, \mathbf{A}) + \omega_i = \alpha_0 + \alpha_1 h_0 + \alpha_2 \ln(B_i) + \theta' \mathbf{z}_i + \gamma' \mathbf{A}_i + \omega_i \quad (11)$$

with  $\alpha_1 < 0$ ,  $\alpha_2 > 0$ , and  $\theta < 0$  (based on Eqs. (A1)–(A4) at Appendix A); where  $M_i$  is investment in health proxied by the per capita private healthcare expenditure of household  $i$ , and  $\omega_i$  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 Trivedi (2003), the variable  $h_0$  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  $A_i$  includes the disease incidence of household members, and the age, gender, years of education, and marital status of the household head. For the variable  $z_i$ , 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 1.4 km, 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%) 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 GHS 56, with a standard deviation of 49.<sup>5</sup> The per capita out-of-pocket healthcare expenditure in Ghana was GHS 49.74 while the per capita total household expenditure was GHS 3117. The corresponding figure for urban areas, which was higher than for rural areas, was GHS 3926 (GSS, 2014b). From the data we collected in Obuasi Municipality, which is predominantly urban area, the per capita household expenditure was about GHS 3900.

The respondents (i.e., household heads) were asked to evaluate their health status on a scale of 0 to 100 subjectively.<sup>6</sup> Studies have found that, when health information is lacking, individuals' subjective health (SH) 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%, which is quite high. Only 21% 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-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% of households had most of their hospital bills paid by a non-member of the household.

### 5.2. Regression Results

Two sets of regression equations are estimated: two-staged least squares compared with ordinary least squares 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 Tables B1 (Appendix B) and 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% 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% 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% 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.

The coefficient of perceived health status is negative and statistically significant at 1% 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

**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<br>(0.064)**   | 0.413<br>(0.178)**   | 0.413      |
| Per capita household health status (0–100%)                          | −0.043<br>(0.005)*** | −0.128<br>(0.014)*** | −0.128     |
| Log (distance between house and the nearest major mine)              | −0.119<br>(0.031)*** | −0.118<br>(0.042)*** | −0.118     |
| Male (1/0)   | 0.006<br>(0.088)     | −0.167<br>(0.116)    | −0.132     |
| Household head is married (1/0)                                      | −0.057<br>(0.079)    | 0.082<br>(0.11)      | 0.055      |
| Age of household head  | −0.005<br>(0.003)*   | −0.018<br>(0.004)*** | −0.737     |
| Greater portion of hospital bills paid by non-household member (1/0) | −0.283<br>(0.082)*** | −0.246<br>(0.107)**  | −0.044     |
| _cons  | 6.154<br>(0.690)***  | 11.528<br>(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            |            |

Standard errors in parentheses.

\* Significance at 10%.

\*\* Significance at 5%.

\*\*\* Significance at 1%.

<sup>5</sup> At the time of the survey (May–July 2014) the exchange rate was US\$1.00 = GHS3.40.

<sup>6</sup> 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 and Akpalu, 2011). Previous studies on regulatory compliance in fisheries, for example, have employed a similar scale (see e.g., Kuperan and Sutinen, 1998; Eggert and Lokina, 2010).

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. With regards to policy making, improving the health status of the residents may have positive feedback effect on health care expenditure.

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% level, with an elasticity coefficient of 0.41, suggesting that healthcare is a normal good. Since mining communities in Ghana are bedevilled with high poverty rates, public policy aimed at improving the incomes of the residents within the mining communities are likely to promote good health.

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% level and the corresponding elasticity coefficient is  $-0.12$ . This implies that healthcare expenditure may increase by 0.12% as a result of a 1% decrease in the average distance from the residence to the mining site. Conversely, the marginal willingness to accept compensation for healthcare expenditure (curative and preventive) because 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 hazardous substances 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. Surprisingly, the variable had the highest elasticity coefficient,  $-0.74$ . This is quite intriguing and 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 is an open empirical question, which cannot be determined a priori. A cross country study on Africa found that national healthcare expenditure is not significantly determined 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. It is therefore unclear whether this finding is indicative of the income or earnings of the household heads (i.e., older household heads, all else being equal, have less income and assets and, for that reason, have less money to spend on healthcare). If income poverty is the driving force of the low spending, then public policy may be required to support older people.

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 Willingness to Accept (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 Eq. (11), the negative relationship between the two variables, if all other explanatory variables are evaluated at their mean values, can be illustrated by Fig. 2. Households closest to a

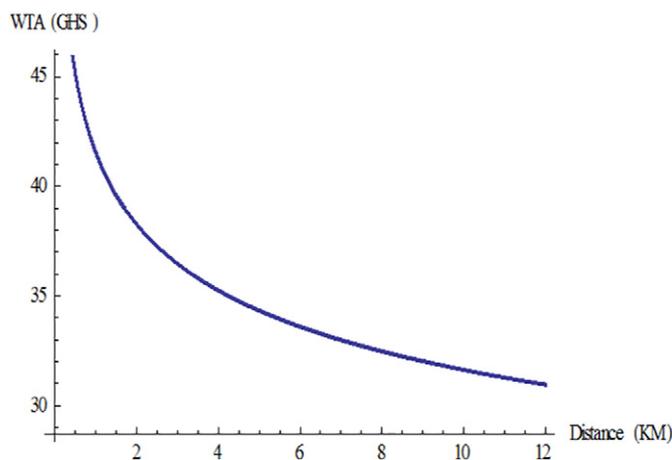


Fig. 2. Willingness to accept compensation: the proximity-health expenditure trade-off.

major mining site (0.02 km) were willing to accept a minimum of GHS 68.79 per annum per household member, while those farthest from the mine (10.0 km) required an average compensation of only GHS 33.27 per annum per household member.

The total willingness to accept (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 GHS 23,348.14 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 $\text{NO}_2$ Concentration

Per the World Health Organization (WHO), a strong correlation generally exists between concentrations of  $\text{NO}_2$  and other toxic pollutants (WHO, 2006). Thus,  $\text{NO}_2$  is often used as a proxy or surrogate for the presence of pollutants 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  $\text{NO}_2$ .<sup>7</sup> Using the corresponding figures from Table B2 (i.e.,  $-1.87^{-1}$ ), which is based on data Aragón and Rud (2015), and Table 2 (i.e.,  $-0.118$ ), the elasticity coefficient is 0.06. Thus, a 10% increase in  $\text{NO}_2$  concentration will increase the WTA compensation by 0.6%.

## 6. Conclusion

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 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 many variables including current and long-term health status, and household income.

The inverse relationship between the age of household head and health care spending found in this study call for further research to enrich public policy. Thus, as noted earlier, it is unclear whether this is due

<sup>7</sup> Note that if  $y = f(x(v))$ , then the elasticity of  $y$  with respect to  $v$  is  $\eta_{yz} = \left(\frac{dy}{dx}\right) \cdot \left(\frac{dx}{dv}\right)$ .

to asset ownership effect or that younger individuals in the mining community are generally in poorer health condition compared to their older counterpart, as mining pollution has intensified over time.

Secondly, private health expenditure of residents in mining communities may decline if policies that promote good health are promoted. This may include preventive measure that minimizes exposure to pollutants.

Furthermore, the finding that wealthier households spend more on healthcare than their poorer counterparts suggests that public policies that create jobs and improved earnings may promote good health among residents of mining communities, as most live in poverty.

Finally, by directly estimating mining pollution impact on healthcare spending, compensation for exposure to such pollution could be calculated and victims better compensated. Thus, the distance to the tailings could be the yardstick for determining compensation for people residing in mining communities, all else being equal.

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 bio-physical study was employed to draw the link between distance to tailings and pollution concentration within the mining communities. Furthermore, the study uses a historical mining community in Ghana, where exposure has lasted for over a century as a case. The findings may therefore not strictly hold for recent mining areas. Future extensions of this work should consider these limitations and employ physical and biochemical data to enrich the analysis.

**Appendix A**

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

$$\frac{dM}{d\mu} = \frac{-(\rho - h_0 - 2\mu M)}{(u_{MM}(\bullet) - \mu^2 - \sigma^2)} > 0 \tag{A2}$$

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

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

**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<br>(0.255)                   | -0.053<br>(0.019)***                   |
| Male (1,0)   | -1.905<br>(0.747)**                 | 0.026<br>(0.055)                       |
| Household head is married (1,0)  | 0.555<br>(0.669)                    | -0.154<br>(0.049)***                   |
| Age of household head  | -0.151<br>(0.024)***                | -0.003<br>(0.002)                      |
| Greater portion of hospital bills paid by non-household member (1,0)                     | 0.688<br>(0.683)                    | 0.149<br>(0.05)***                     |
| Per capita household incidence of lower respiratory tract infections (LRTI) <sup>a</sup> | -1.434<br>(0.84)*                   | 0.057<br>(0.061)                       |
| Per capita household incidence of diabetes <sup>a</sup>                                  | -1.704<br>(0.908)*                  | 0.105<br>(0.066)                       |

**Table B1** (continued)

|  | Coefficients                        |  |
|--|-------------------------------------|--|
|  | Per capita household health status% | Log (per capita household expenditure) |
| Per capita household incidence of cardiovascular diseases <sup>a</sup> | -3.972<br>(1.046)***                | -0.009<br>(0.076)                      |
| Per capita household incidence of neurological disorders <sup>a</sup>  | -1.693<br>(0.915)*                  | -0.06<br>(0.067)                       |
| Skin infections recurrence per household <sup>a</sup>                  | -0.304<br>(0.114)***                | -0.024<br>(0.008)***                   |
| Per capita household labour force <sup>a</sup>                         | 1.244<br>(0.938)                    | 0.624<br>(0.069)***                    |
| Cardiovascular exercise <sup>a</sup>                                   | -1.813<br>(0.564)***                | 0.087<br>(0.041)**                     |
| Years of education of household head <sup>a</sup>                      | 0.147<br>(0.069)**                  | 0.014<br>(0.005)***                    |
| _cons  | 88.58<br>(1.482)***                 | 7.739<br>(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                                  |

Standard errors in parentheses.

\* Significance at 10%.

\*\* Significance at 5%.

\*\*\* Significance at 1%.

<sup>a</sup> Instrumental variable.

**Table B2**

Regression results of bootstrap data of effect of distance (km) on nitrogen dioxide (NO<sub>2</sub>) concentration.

| Number of replications     | 100                  | 500                  | 1000                 |
|----------------------------|----------------------|----------------------|----------------------|
| Distance (km)              | -0.022<br>(0.006)*** | -0.022<br>(0.007)*** | -0.022<br>(0.007)*** |
| _cons                      | 0.825<br>(0.139)***  | 0.825<br>(0.209)***  | 0.825<br>(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                |

Bootstrapped standard error in parentheses.

\*\*\* Significant at 1%.

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