Effect of mining activities on birth defects in Armenia

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Contents

Abstract

The aim of this paper is to analyze the results of the Demographics and Health survey jointly conducted by National Statistical Service of Armenia, Ministry of Health of Armenia and the DHS Program to identify the effect of mining on the health of population. Mining activities are considered to cause lung, neurotoxic, dermatological, reproduction disorders, poisoning, psychological conditions, etc.

The mining industry is the main sector in the Armenian industry. In 2017, it accounted for about 30% exports of the country. According to reports, there are around 670 mines on the territory of Armenia, out of which around 400 are currently being exploited. The largest of these mines are located in Kajaran, Agarak, Akhtala, Sotk, Teghut.

According to Head of Center's Environmental Geochemistry Laboratory, 57% of population of Yerevan lives in contaminated conditions due to ground pollution caused by mining activities (Hetq, 2011). This pollution is becoming a part of the human food chain either through the irrigation water which delivers the contaminants to the herbs and vegetables, or directly through the potable water.

The DHS survey was being conducted in Armenia starting from 2000, and includes multiple questions related to housing conditions and household population, marriage and sexual activity, fertility, health records, etc. The survey also provides slightly modified locations of the respondents. In this paper I will filter out the population that leaves in proximity to mines and analyze how their wealth is being affected as a result of the mining activities that are being conducted in their surroundings.

Introduction

Armenia is rich in a number of metal ores: iron, copper, molybdenum, lead, zinc, gold, silver, aluminum, and rare metals which naturally occur in the aforementioned ores. Among all these, copper and molybdenum are the most important ores for the Armenian economy. Kajaran, the largest mine in Armenia, is claimed to have 2.24 billion tones of copper and molybdenum ores. This represents 6% of global reserves for these metals. In addition, this giant mine accounts for 60% of the mining of the country. If the current rate of mining at Kajaran persists, the mine can potentially operate for another 100-120 years.

In 2015, the 16.4% of the industrial output was coming from mining. The following year, that number increased to 16.7%. The share of the industry in the Armenian exports is over 50%. The mining industry accounted for 4.4% GDP in 2015 and 2.6% in 2016.

According to official data, the mining industry employs 10,000 people with an average salary twice as large in comparison with the national average. All these facts jointly make mining industry a major source for government incomes: companies operating in these sectors are among the largest taxpayers in Armenia.

Mining industry has a long history in Armenia. Alaverdi copper mine was first exploited in 18th century. The Kajaran mine first started operations in 1840. The present-day Kajaran mine was opened in the mid-20th century.

Throughout the Soviet era Armenia was the third largest mining country in the union, following Russia and Kazakhstan. During that period Kapan, Sotk, Agarak, Alaverdi, etc. were the largest mines operating in the country.

The expansion of the mining industry, despite the large incomes that it is bringing to the country, is usually met with social disagreement and protests. The social costs of mining activities include environmental risks, human health risks, unsustainable use of natural resources, etc. The largest movement against mining activities were initiated in the country in mid-2000s, when Vallex started preparations for exploitation of Teghut mine. Another public movement is currently active, trying to prevent Lydian Armenia from opening a gold mine in Amulsar.

The main issues related to the mining are the emissions of gases and contaminants into the surrounding environment, as well as the processing of the tailings that remain as a residue and waste of mining. Both through the gas emissions and through the tailings the mines emit various chemical compounds into the atmosphere and the environment. Most of these emissions are harmful for surrounding plants, animals and humans. Moreover, the emissions may be transferred to remote areas. This can be done either through winds that transfer gas emissions, or through the rivers in which the mine tails are usually being dumped. Even if the mine tailings are not being spilled directly into the river, the contaminants can be absorbed through the soil into the underground water basins and streams and eventually appear in the rivers, lakes and other water basins. Furthermore, the contaminants that are being absorbed by plants and/or animals can be transferred to the humans through the food chains.

Trace metals are known to cause a wide range of adverse health effects because metals do not break down, are excreted very slowly, and accumulate in the body. Exposure to pollutant trace metals can cause many ailments including dermatitis, cardiovascular diseases, central nervous system (CNS) disorders, lung, kidney and liver damage, birth defects, and cancer. (Kurkjian, 2000)

All in all, mining is a major source of income in Armenia, but it also contains multiple risks to the environment and the health of the local population.

Literature review

Previous research indicates that there is a direct relationship between the residence near mining areas and human health, particularly, the birth weight and the cases of miscarriage and/or stillbirth. Residence in a coal mining area serves as an indicator of environmental contamination from the mining industry. The environment profoundly influences the genetic constitution of newborns and impacts transplacental exposure that negatively affects birth outcomes. Specifically, molecular studies have documented significant transplacental transfer of contaminants, including polycyclic aromatic hydrocarbons (PAHs) and environmental tobacco. In addition, the fetus may be vulnerable to pollution stored inside the mother's body (Ahern, Mullett, MacKay, & Hamilton, 2010).

Using spatially derived covariate, Ahern et al. (2011) found that the spatial mountaintop mining variable and county birth defect percentage covaried across the study area. This indicates a potentially strong relationship between birth defects of a county and mountaintop mining activity in that county's neighborhood. Findings show significantly higher prevalence rates for birth defects overall, and for six of the seven types of anomalies examined in mountaintop mining areas versus other mining and non-mining areas, consistent with previous research showing greater surface, air, and water disturbance specific to surface mining areas where mountaintop mining occurs. Moreover, their research indicated that the results from the spatial analysis and that the impacts of mountaintop mining extend beyond the immediate site of mining operations.

Unfortunately, there is a lot of evidence that the mining operations are not being properly done in Armenia. Kurkjian et al. (2004) stated that the discharges of waste from mining and industry in Armenia, including discharges into the Debed River, have historically been inadequately controlled. As a result, the concertation of the lead along the stream was at some locations much higher in comparison with World Health Organization standards.

Gevorgyan et al. (2014) measured the soil contamination by the Zangezur mine. It is possible to state that the operation of Zangezur copper and molybdenum combine has caused significant pollution of the soils with heavy metals (Mo, Cu, Pb, As, Zn, Ni). Heavy metal pollution degree in the soils around the mining complex may have posed risks to agricultural production and the health of especially younger population in the territory. High environmental risks were posed predominantly by molybdenum, arsenic, copper and lead.

Petrosyan et al. (2003) provided further evidence about the lead contamination in the mining communities. They found elevated lead levels in residential soil and dust in the study towns. Lead levels were the highest in the smelter town of Alaverdi, particularly in residential Sectors 3 and 5, which are the closest to, and downwind from, the polymetallic smelter. Children typically spend significant amounts of time outside playing in their yards and could ingest lead contaminated soil and dust through hand-to-mouth activities. Kurkjian et al. (2002) suggested that the environmental aspects such as the dry climate, the strong winds, and the presence of bare soil can create conditions for resuspension of settled lead-contaminated dust into the air, contributing to its dispersion and potential increase of human exposure.

For the purpose of this analysis child's birth weight was chosen as a dependent variable to test for the effects of mining. Research suggests that there is a direct relationship between the birth weight and the health outcomes in future. Valdez et al. (1994) stated that in normotensive and non-diabetic young adults, birthweight is significantly inversely associated with fasting serum insulin concentrations and with truncal fat deposition. Systolic and diastolic blood pressures, and 2-h post load insulin also tend to decrease, although perhaps less consistently, with increasing birthweight. These associations are independent of confounding variables such as sex, ethnicity, and current socioeconomic status. Furthermore, we have shown that insulin resistance (as assessed by fasting insulin levels) tracks the distribution of the IRS traits across the BMI-birthweight tertile categories. Barker et al. (1991) claim that blood pressure and risk of hypertension among men and women aged around 50 are predicted by a combination of placental weight and birth weight. The highest blood pressures and risk of hypertension were among people who had been small babies with large placentas.

Summing up, the prior research indicates that the mining in Armenia is having an adverse result on the environment and human health. The concentrations of contaminants are discovered in soil, air and water basins in the territories adjacent to the mines. Furthermore, there is also an evidence of relationship between the proximity to the mines and the birth defects in the settlements that are closely located to the mines. Also, the research claims that the birth weight might be a good indicator of future health and can be affected by the mining activities.

Data

The data used to conduct the analysis was taken from the Demographic and Health Survey program's 2015/2016 survey. It was the fourth time that this survey was conducted in Armenia. Previously it was conducted in 2000, 2005 and 2010. The aim of the survey was to provide up to date estimates about the key demographic and health indicators. *More specifically, the ADHS collected information on fertility and abortion levels, marriage, fertility preferences, awareness and use of family planning methods, breastfeeding practices, nutrition, maternal and child health, childhood mortality, domestic violence against women, child discipline, awareness and behavior regarding HIV/AIDS and other sexually transmitted infections (STIs), and other health-related issues such as smoking, tuberculosis, and anemia.* The survey results data was separated into several datasets. For the purpose of this analysis the individual dataset was taken, which contains information about each individual respondent. The data is formed of 6,116 observations and 5670 variables. For the purpose of this analysis, the data was filtered out and several variables containing basic information about the respondents, their health, and the health of their children at birthtime was taken.

The table below provides the names of the variables and their descriptions.

Variable Name	**Description**
Education Years	Number of years of education of the respondent
Wealth	Wealth index of the respondent
Teghut	Distance from the mine of Teghut, measured in km
Akhtala	Distance from the mine of Akhtala, measured in km
Alaverdi	Distance from the mine of Alaverdi, measured in km
Sotk	Distance from the mine of Sotk, measured in km
Kajaran	Distance from the mine of Kajaran, measured in km
Drmbon	Distance from the mine of Drmbon, measured in km
Close	Dummy variable indicating whether the distance from the mine is less than 40 km (1-less than 40 km, 0- more than 40 km)
Stillbirth	Dummy variable indicating whether the individual had a stillbirth (1– had a stillbirth, 0- did not have a stillbirth)
Miscarriage	Dummy variable indicating whether the individual had a miscarriage (1– had a miscarriage, 0- did not have a miscarriage)
Weight	The weight of the respondent's child at birth, measured in grams
Minimum	The minimum distance between the respondent's place of the residence and the six mines

The average distances from each of the mines are indicated in the figure below.

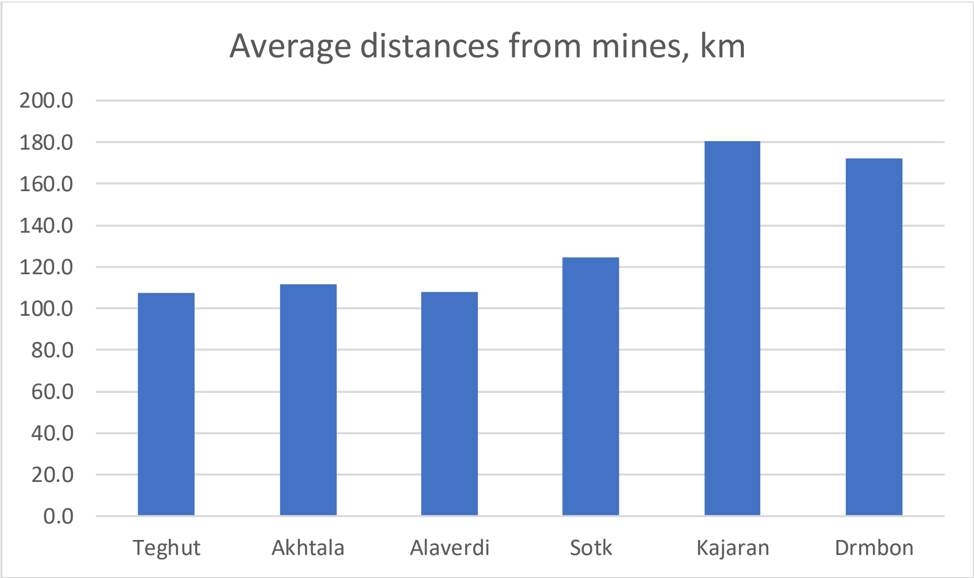

Figure 1-Average distances between the respondents and mines

Overall minimum distance recorded between an individual respondent and a mine in the dataset is equal to 2.16 kilometers. The maximum distance recorded is equal to 284.67 kilometers.

The distribution of income of the respondents is represented in the following chart.

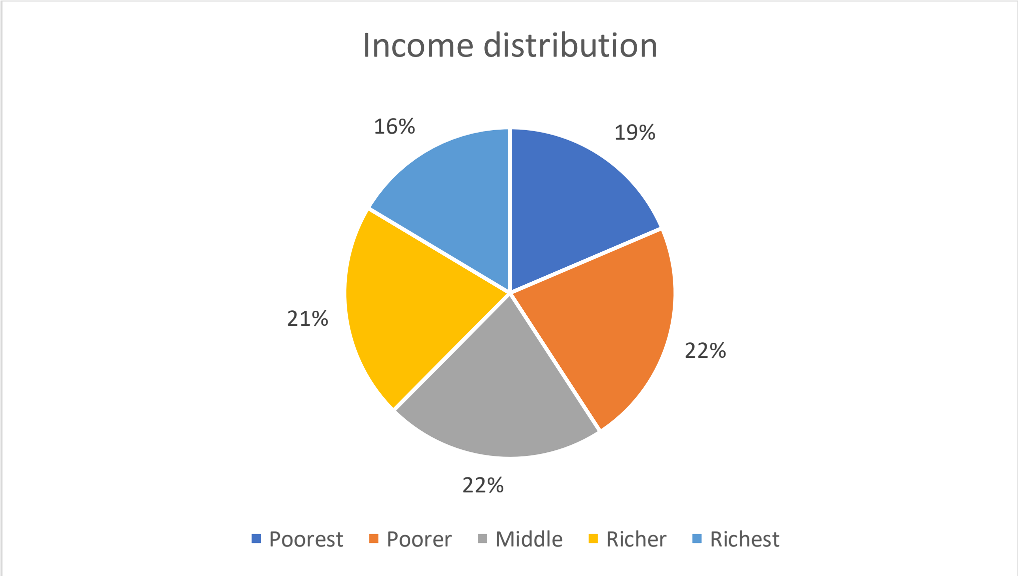

Figure 2 - The distribution of respondents by incomes

Out of 6116 respondents 1137 were classified as poorest, 1358 were classified as poorer, 1324 were classified as middle, 1293 as richer and 1004 were classified as richest. The classification of people based on wealth is done by DHS using wealth index. *The wealth index is calculated using easy-to-collect data on a household's ownership of selected assets, such as televisions and bicycles; materials used for housing construction; and types of water access and sanitation facilities.*

The chart below represents the distribution of respondents by education level.

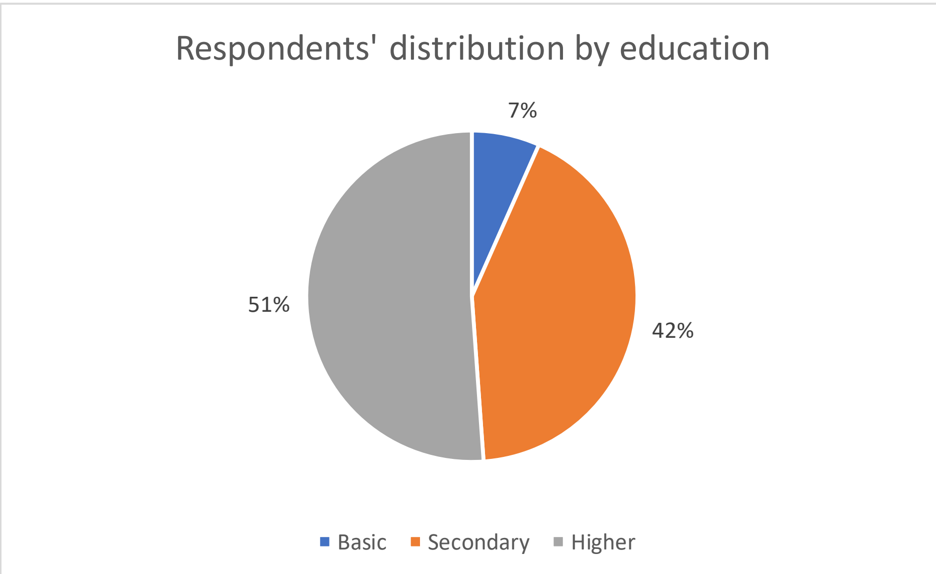

Figure 3 - The distribution of respondents by education

Out of 6,111 respondents that provided information about their education level, 406 had basic education, 2,580 had secondary education and 3,125 had higher education.

The dependent variables chosen for the analysis are the number of miscarriages and number of stillbirths. The goal was to see whether the proximity to the mines is having an impact on the number of miscarriages and stillbirth, thus we can conclude that there is a relationship between the distance from the mines and the reproductive health of the population.

Since in the majority of cases the respondents did not have any miscarriages and stillbirths, and in the majority of the cases when these were present their number was not large, it would be hard to estimate the exact number of miscarriages and stillbirth. The Ordinary Least Squares Regression would not give valid results. For that purpose, the variables that representing the number of miscarriages and stillbirths were converted into dummy variables. In cases there were any miscarriages, the dummy variable got a value 1, in case there were no dummy variables, the dummy variable got a value of 0. The same was done with stillbirth variable.

The chart below provides information about the number of stillbirths and miscarriages in the overall population.

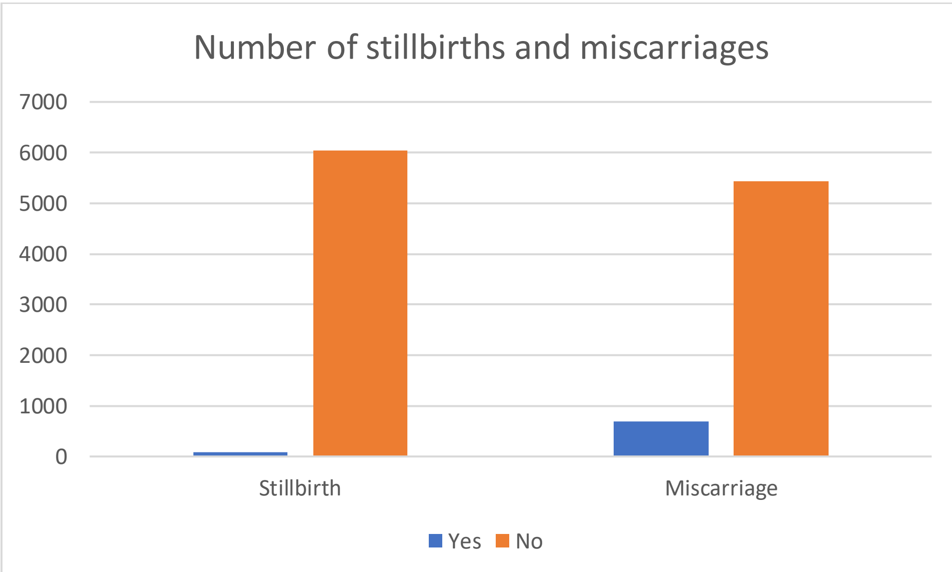

Figure 4 - Number of occurrences of miscarriages and stillbirths among the respondents

Out of the 6,116 respondents, 83 ever had stillbirths and 687 had miscarriages.

The chart below represents the distribution of the birth weights of the respondents' children.

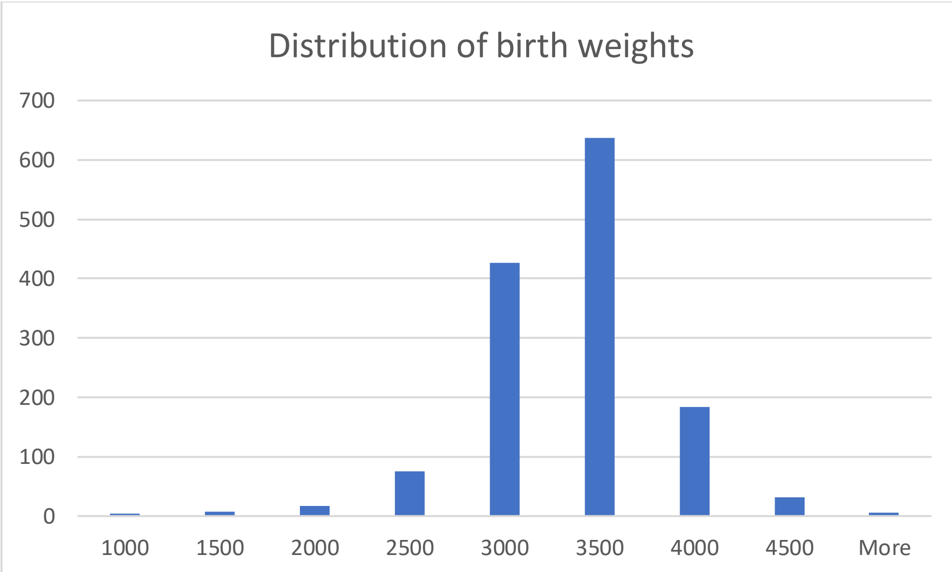

Figure 5 – The distribution of the weights of the newborns

Out of 6,116 respondents 1386 provided information about the birth weight of their children.

The matrix below represents the correlation matrix of the variables in the dataset.

	Education Years	*Wealth*	*Teghut*	*Akhtala*	*Alaverdi*	*Sotk*	*Kajaran*	*Drmbon*	*Close*	*Stillbirth*	*Miscarriage*	*Weight*	*Minimum*
Education Years	1												
Wealth	0.35	1											
Teghut	-0.04	0.03	1.00										
Akhtala	-0.04	0.03	1.00	1.00									
Alaverdi	-0.03	0.03	0.99	0.99	1.00								
Sotk	-0.06	-0.04	-0.15	-0.19	-0.28	1.00							
Kajaran	-0.03	-0.07	-0.79	-0.81	-0.86	0.69	1.00						
Drmbon	-0.06	-0.05	-0.38	-0.42	-0.50	0.94	0.85	1.00					
Close	0.00	-0.01	0.03	0.03	0.06	0.04	-0.12	-0.12	1.00				
Stillbirth	-0.05	-0.14	0.01	0.01	0.01	0.00	-0.01	0.00	0.00	1.00			
Miscarriage	0.01	-0.02	-0.08	-0.08	-0.08	0.05	0.08	0.07	-0.02	0.02	1.00		
Weight	0.03	0.04	-0.06	-0.06	-0.05	0.00	0.04	0.01	-0.01	0.02	-0.02	1.00	
Minimum	-0.05	0.00	0.19	0.18	0.11	0.29	0.14	0.41	-0.60	0.02	0.02	0.00	1

Figure 6 - The correlation matrix of the variables in the datasets

Methodology

Three variables were chosen from the DHS dataset to test for the impact from mining. The first variable is the child's weight at birth. To analyze the impact of the mining activities, OLS regression model was prepared to understand the impact of mines on the birth weight.

Starting from 2010, the DHS also provided geographic data about the respondents. In order to ensure the privacy of the respondents, the DHS shifted the geographic locations of the respondents. In urban areas, the coordinates of the respondents were displaced by no more than 2 kilometers, while in rural areas the coordinates were displaced by no more than 5 kilometers. In 1% of rural cases the displacement was less than 10 kilometers.

In order to conduct the analysis, the coordinates from the dataset with geographical information were matched with the information in the datasets of the individual respondents using the ID's of each of the respondents.

Several mines were selected to test for their effects on human health. The selected mines were Akhtala, Alaverdi, Teghut, Kajaran, Sotk and Drmbon. After that, the coordinates of these mines and the coordinates of each of the respondents were used to calculate the distance between each of the individuals and each of the above-mentioned mines.

There are also variables indicating the cases of miscarriages and stillbirths among the respondents. The initial data contained information about the number of miscarriages and stillbirths, and this variable were transformed into dummy variables, were the value of 1 stands for the cases of miscarriages and stillbirths, and the value of 0 stands for the cases when these outcomes were not present.

Since the variables containing information about the stillbirths and miscarriages are binary, OLS cannot give valid results. In order to get reliable results, logistics regression was performed to estimate the probability of the outcomes of those variables.

In addition, a new variable was created out of the six variables containing information about the distances of the respondents from the mines, indicating the least distance between each individual respondent and any of the six mines. This variable is supposed to provide an aggregate overview about what is the effect of the distance.

Results

As it is obvious from the correlation matrix, many of the variables that indicate the distance between the respondent's residence place and the mines are correlated with each other. This might be explained by the fact that some mines are located close to each other, in the same regions of the Armenia.

In order to eliminate the issues of multicollinearity, the variables with distances were used separately together with the variable for wealth and education years in the regression model.

Since the birth weight variable was reported only by some women, only 1386 were left out of the 6,116 observations. Since all male respondents were filtered out, the education years and wealth variables are related to the mothers of the children whose birth weights are being estimated.

OLS Regression Results			
Dependent variable: Birth weight			
Model	1	2	3
Education Years	212.75 ***	199.6 ***	251.87 ***
Teghut	4.74 ***		
Minimum		8.04 ***	
Close			117.28 *
Adjusted R squared	0.949	0.952	0.943
Number of observations	1386	1386	1386
Significance level: * p<.1; ** p<.05; *** p<.001			

The first model included three variables: distance from Teghut, wealth and education years. The adjusted R squared of the model is equal to 94.9%, which means that 94.9% of birth weight's variation is explained by the variance of the other variables. The coefficient of Teghut variable is 4.74, which means that if the distance to the Teghut decreases by 1 kilometer, the weight of the newborn increases by 4.74 grams, in case other variables are constant. The coefficient of education is 212.7, which means that each additional education year of the mother resulted in 212.7 grams of extra weight of the newborn, everything else constant.

In case of all other variables describing the distances from the mines the models are giving comparable results. The coefficients for those variables vary from 4 to 8, meaning that 1-kilometer decrease in the distance resulted in 4 to 8 grams of increase in the weight. The adjusted R squared are also comparable to the first model, ranging from 94 to 97 percent.

In order to prepare one model which will encompass information about all the mines in the dataset the Minimum variable is used, which measure the least distance out of all six mines. By using this variable, I will also be able to get a result that does not depend much on such specifics of the mine as their location, altitude, type of the mineral resource that is being excavated, chemicals used in mining process, type of tailings, etc.

The adjusted R squared for this model is 95.2%, which means that 95.2% percent of variation of the weight at birth is explained by the variation in the minimum distance from the mine and the number of years of education of the mother.

Another model was created using the variable “Minimum”. The coefficient of the “Minimum” variable is 8.04, which means that one unit decrease in the distance to the mines will cause a 8.04 grams increase in the weight of the new born, in case the other variable is constant. The coefficient of the “Education Years” variable is 199.6, which means that if the mother’s number of education years is higher by one year, the child’s weight will be higher by 199.6 grams.

Similar results were received by integrating the variable “close” in the model.

The adjusted R square is high, equal to 94.3%, which means that 94.3% of variation of the birth weight is explained by the variation in the independent variables.

The coefficient of variable “Close” is equal to 117.28, which means that if the respondents house is located less than 40 kilometers from any of the six mines, her child’s birth weight will be less by 117.28 grams in comparison with those whose house is located more than 40 kilometers away from the mines.

As the second part of the analysis, I decided to prepare models which will estimate the relationship between the occurrences of miscarriages and/or stillbirths and the distances from the mines. For this purpose, I used the variables “Stillbirth” and “Miscarriage” and prepared logistic regression models in order to estimate the outcomes of these binary variables.

Logit Regression Results		
Dependent variable: Miscarriage		
Model	1	2
Minimum		-0.0585 *
Close	-0.1934	
Education Years	-0.1742 ***	-0.1599 *
Number of observations	6116	6116
Significance level: * p<.1; ** p<.05; *** p<.001		

In the first model, the variable "Close" was not significant, since its p-value is equal to 0.133.

Logistic regression was also conducted using the variable "Minimum" as the independent variable. Both education and minimum distance variables are significant. The coefficient in this case is equal to -0.0585. Its exponent is equal to 0.997, which means that one unit decrease in the minimum distance from the mines increases the odds of miscarriage by 0.003%. The exponent of the coefficient of the education variable is equal to 0.852, which means that an additional year of education of the parent decreases the odds of the miscarriage by 15%.

Logit Regression Results		
Dependent variable: Stillbirth		
Model	1	2
Minimum		-0.0043 *
Close	-0.2104	
Education Years	-0.3816 ***	-0.3514 ***
Number of observations	6116	6116
Significance level: * p<.05; ** p<.01; *** p<.001		

The same is true in regards with the variable "Stillbirth". In case of having stillbirth as dependent variable, the variable "Close" is again non-significant, so I will not use the first model.

The exponent of the coefficient of variable "Minimum" is equal to 0.995. This means that people that leave in further areas from the mines have 0.005 % reduction in odds of having a stillbirth in comparison with people who live close to the mines. In other words, people living in adjacent areas to the mines are somewhat more likely to have stillbirth and/or miscarriages.

The exponent of the coefficient of the variable “Education years” is equal to 0.703. This means that an additional year of education of the parent is decreasing the odds of stillbirth by 30%.

Thus, all the models that were significant indicate a similar pattern: closer is the respondent to the mine, somewhat more likely she is to have a miscarriage and/or a stillbirth.

Conclusion

As previous research suggested the mining activities have an effect on such birth defects as miscarriages, stillbirths, and low birth weights. The research that was conducted in the scope of this project provided similar results.

The analysis was done using the data provided by Armenian Demographics and Health Survey. Main variables used for the analysis were the distances between the survey respondents' residence locations and various currently operating mines located in different parts of Armenia.

The results of regression indicated that the birth weight of children is positively related to the distance from the mines. Thus, the further is the house of the resident from the mine, the higher is the expected birth weight of their children. These results do not depend on a specific mine. They are similar both for individual mines and for the variables that contain aggregated information about all the mines included in the analysis.

In addition, other models were prepared to estimate the likelihoods of miscarriages and stillbirth. These variables were regressed with the variable indicating the least distance from the respondent's residence and any of the six mines included in the research. The result is that the closer the respondent lives to the mine, the more likely she is to have a miscarriage and/or a stillbirth.

Summing up, the research conducted in this paper provides an evidence that the mining activities in Armenia are having a negative impact on human health, particularly in reproductive health in terms of their severe effects on the birth weight of the children and the instances of miscarriages and stillbirths.

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