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Egalitarian Cost-Sharing of Technology to Improve Gold Miners' Health

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Abstract

Gold ore mining and refining are processes mainly carried out in small, rural communities in developing countries. As mercury is used in refining gold ore, working environments can be hazardous. The aim of this paper is to explore cost sharing of expensive technology that reduces health hazards in low-income communities using economic theory. With high competition in communities with limited employment opportunities, the revenue of each producer will decline as the number of producers increases. Therefore, as long as the cost of reducing health hazards associated with production is high, producers will have a decreasing incentive to share these costs. However, if the community is egalitarian, the incentive to share costs will not decline, even if the cost of reducing such health hazards is high.

Keywords: gold mining, community, mercury, health hazards, cost sharing, egalitarianism.

JEL Classification: Q53, O13, D29.

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1. Introduction

In rural areas of developing countries, where employment opportunities are limited, between 10 and 15 million people work as artisanal, or small-scale, miners of gold. Of these, 30–45% (4.5 million) are women, and 2–3% (300,000) are children (Marcello *et al.*, 2004). These miners use little to no mechanization to mine and refine gold ore.

A common method for refining gold in artisanal mining is to heat the gold ore to a very high temperature with a mercury amalgam so that the mercury evaporates and gold remains. Unfortunately, this method results in the miners being exposed to high levels of mercury.

Although technology exists for mitigating the health risks caused by inhalation of mercury fumes, the introduction of such technology is slow (UNEP, 2014).

* This paper is a modification of Sato(2016).

Some research on this topic has been performed in the public health field. Bose-O'Reilly *et al*. (2010), showed that working conditions in which mercury is used to refine gold are extremely hazardous, with children being the most vulnerable. A field study conducted between 2003 and 2004 on the health of children refining gold found evidence that such children exhibit symptoms typical of mercury poisoning, such as ataxia (Bose-O'Reilly *et al.*, 2008).

In Sulawesi in Indonesia, where the research of Bose-O'Reilly *et al.* (2008) was performed, the number of households increased at an average rate of 2% per year over the 5-year period from 2005 to 2010, despite the damage inflicted by the Sumatra earthquake of March 2005. Furthermore, according to census results, the number of households continues to grow (data available from the Statistics Indonesia website – http://www.bps.go.id/). In this paper, I will attempt to examine the above-mentioned health hazards in the context of this population growth.

In this paper, I will show the following from an economic theory perspective: in rural areas of developing countries, where employment opportunities are limited to mining and refining gold ore, when the number of low-income households increases, the price of gold as a raw material will decline, which will decrease household incomes. Therefore, as long as the technology to reduce the health risks associated with production is expensive, producers will have a decreasing incentive to

share the costs of the technology. However, egalitarianism within the community may enable both expansion of the community and the reduction of health risks.

This paper is organized as follows. In the next section, I set up a model based on economic theory. In the third section, I examine incentives for egalitarian cost sharing. In the last section, I offer concluding remarks.

2. Theoretical model

Consider a community that produces gold. This community consists of *n* producers. The quantity of gold produced for the i^{th} producer is denoted as q_i, $i = 1, \cdots, n$. The price of gold *p* depends on the total amount of gold produced by the community $Q = q_1 + \cdots + q_n$, which can be expressed by the following inverse demand equation:

$$p = a - bQ, \tag{1}$$

where both *a* and *b* are positive constants.

This community uses mercury in the gold production process, which is a hazard to producers' health. *C* is the exogenously given total cost of reducing this health hazard.

The community has two types of producers: those who have willingness to share the costs of reducing the health hazards and those who do not. θ_i represents that producer *i* has willingness to share, represented in binary form (i.e., taking either 1 or 0.)

$$\theta_i = \begin{cases} 1 & \text{if the producer is willing to pay} \\ 0 & \text{if the producer is not willing to pay} \end{cases}$$

Let us assume that *k* percent of *n* producers are $\theta_i = 1$, where $k \in (0,1]$. For this paper, I posit an egalitarian cost-sharing rule among these producers. Under this rule, *kn* producers will share *C* equally, so the cost per producer can be expressed as *C/kn*.

The profit of producer *i* is defined as:

$$\pi_i = pq_i - \theta_i C / kn . \qquad (2)$$

Using equations (1) and (2), solving for production volume q_i^* of producer *i* in a Nash equilibrium gives us:

$$q_i^* = \frac{a - b\sum_{j \neq i} q_j^*}{2b} i,\ j = 1, \cdots, n\ . \qquad (3)$$

By aggregating this quantity of production q_i^* for all producers *i* and substituting equation (1), we can derive the equilibrium price of gold p^*:

$$p^* = a - \frac{na}{n+1}\ . \qquad (4)$$

For this equation, if $n \to \infty$, then $\lim_{n\to\infty} a - \frac{na}{n+1} = \lim_{n\to\infty} a - \frac{a}{1+\frac{1}{n}} = a - a = 0$, so we can derive the following lemma:

Lemma 1: If $n \to \infty$, then $p^* = 0$.

When the number of households in a community increases, including migration from other areas, if employment opportunities in gold mining and refining are limited, the number of competitors will increase. Lemma 1 shows that expansion of the community will lead to a decline in the price of gold.

3. Egalitarian cost sharing

The following equation expresses the profit of producer *i* in a Nash equilibrium:

$$\pi_i^* = \frac{a}{n+1}\left(\frac{a - b\sum_{j\neq i} q_j^*}{2b}\right) - \theta_i C / kn . \qquad (5)$$

The first term on the right-hand side of equation (5) denotes the revenue of producer *i*. We denote this as $R_i^*(n)$.We can then obtain the following result using Lemma 1:

Lemma 2: If $n \to \infty$, then $R_i^*(\infty) = 0$.

This shows that when the number of producers in the community increases, the revenue of each producer declines as the price of gold falls. Therefore, if the cost of reducing the health hazards to producers is constant, producers will have less of an incentive to pay.

However, under egalitarian rules, the cost for each producer, *C/kn*, is a decreasing function of *n*. In this case, even if eliminating the health hazard is expensive, the incentive to share costs will not decline, as shown in the figure below. In other words, each producer's income $R_i^*(n)$ will not be lower than the shared cost.

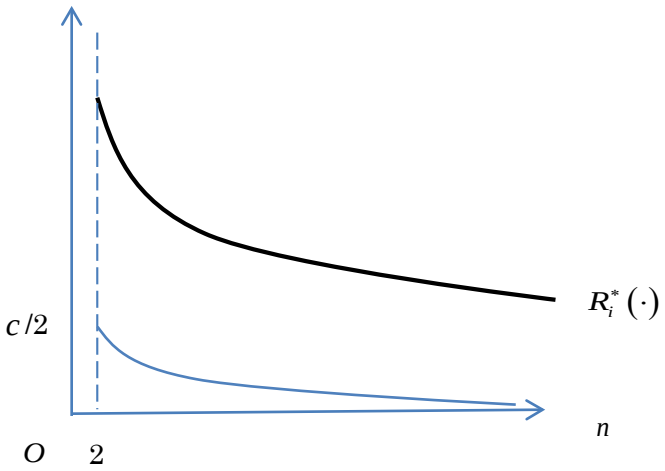

Figure 1. Egalitarian cost sharing

Let us summarize the above findings.

Proposition: If communities with limited employment opportunities are egalitarian, it is possible to both expand the community and share the costs of technology that reduces health hazards associated with production.

4. Conclusion

Low-income people in developing countries continue to use mercury in gold refining. Urgent measures need to be taken to reduce the adverse health effects of the use of mercury, as children are the most vulnerable. To begin to address these concerns, I have approached this problem from an economic perspective.

I show that if low-income communities can share costs under egalitarian rules, even when their population is growing and production competition is intensifying, it will be possible to eliminate one of the economic factors that disregard health hazards.

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